How To Solder Surface-Mount Devices

Many electronics enthusiasts hesitate to build projects involving surface-mount devices (SMDs) because they're 'scared' by the prospect of soldering such tiny parts to a PC board. But it can be done; Jim Rowe shows how.

IT'S TRUE THAT SMDs are not really intended for manual assembly. They're designed for automated pick-and-place machines and reflow soldering ovens.

The problem is that more and more ICs and other components are becoming available *only* in SMD form. As technology marches on, it's becoming necessary for everyone to get used to working with SMDs.

You may already be familiar with simple SMDs, like resistors, capacitors, diodes and transistors. Some of these are shown in Fig.1. Note that they're all shown **twice** actual size, for clarity.

We've used these in various projects published in the last few years, and shown how they can be soldered onto a PC board: use a soldering iron with a fine conical or flattened conical tip and very fine (0.71mm OD) resin-cored wire solder.

How this is done is shown in Fig.2 and Fig.3. The basic idea is to hold the chip or device in place while you tack-solder one or two of its leads to hold it in position. This then allows you to solder all the leads to their pads in the usual way.

It needs to be done very carefully and fairly quickly, so you don't damage either the SMD or the PC pads by overheating. You also need to make sure you don't apply too much solder, which can cause fine solder 'bridges' to short between copper pads or tracks.

If you do get solder bridges, they can be removed by applying the end of some fine desoldering braid to the top of the 'bridge' and briefly applying the tip of your soldering iron to the top of the braid, so the end of the braid heats up to the solder's melting point and 'sucks up' the excess solder by capillary action.

OK, so what is the real problem with SMDs? Put simply, it's not the resistors, but the large SMDs with umpteen dozen closely spaced pins.

Fine-pitch ICs

More and more VLSI (very large-scale integration) devices now come in SMD packages, like the one shown opposite and those in Fig.4 – quad flat packs (QFPs) with anywhere between 44 and 208 leads (pins).

The lead pitch can be as fine as 0.4mm – less than 16% of the 0.1-inch/2.54mm pitch used in most familiar dual in-line IC packages.

The width of the leads can also be as fine as 0.18mm (that's right – only 180μm!), so the actual spaces between the leads can be as small as 0.22mm or 220μm.

Now it *is* possible (just) to solder a 44-lead MQFP device with 0.8mm pitch leads like the IC shown in Fig.4, using a fine-tipped soldering iron and the technique shown on the right in Fig.3.

That's providing you are extremely careful, have a very steady hand and don't mind having to use the soldering braid to remove the almost inevitable solder bridges. If you can do this consistently, then you are a champion!

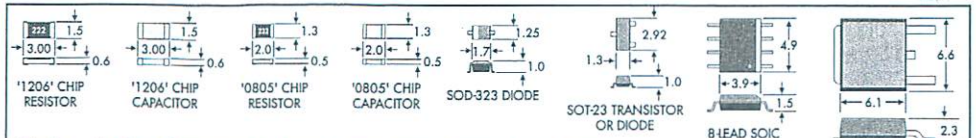
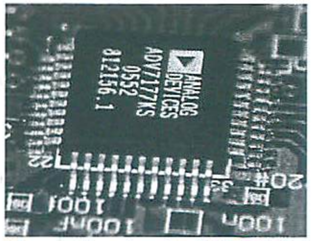


Fig.1: a selection of common SMD components, shown here twice full size (if we showed them normal size they'd be hard to see in some cases).



Close-up view of a 44-lead MQFP device with 0.8mm pitch (lead spacing), after being reflow soldered using a low-cost snack oven.

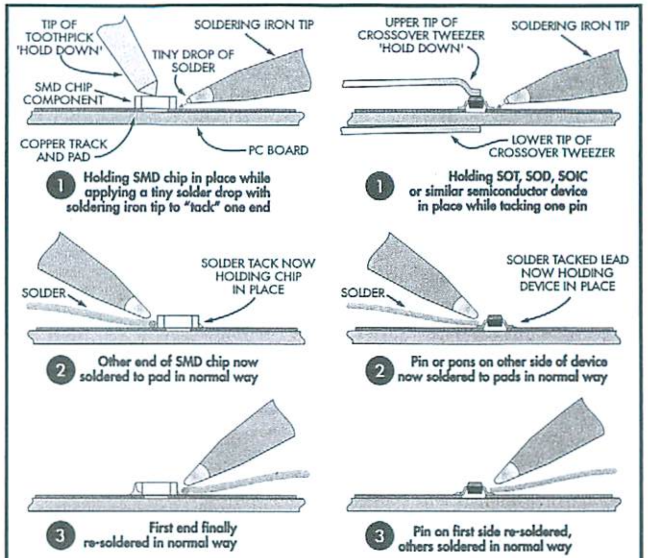


Fig.2: the basic steps involved in manually soldering smaller SMDs like those shown in Fig.1, using a fine-tipped soldering iron and very fine resin-cored wire solder. The steps for resistors and capacitors (left) are much the same as those for SOT, SOD and SOIC devices (right).

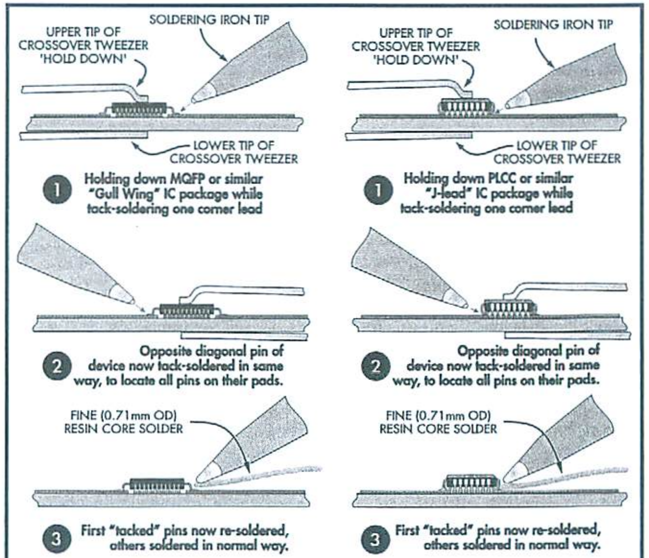


Fig.3: manual soldering of SMD ICs with lead pitches of 0.8mm or more can be done in the same way if you're VERY careful, but be prepared for the accidental creation of solder bridges between leads – and having to remove them using solder wick. As you can see, there's not much difference in approach between 'gull wing' and 'J-lead' devices.

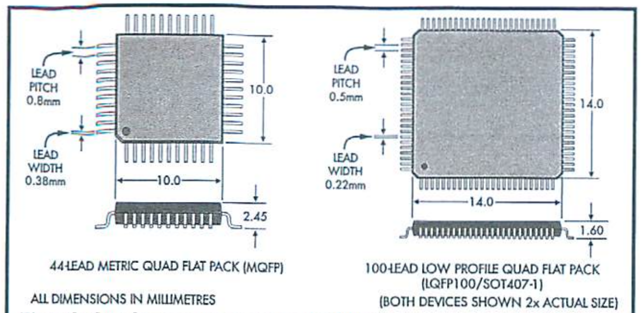


Fig.4: the key dimensions of a 44-lead MQFP device compared with those for a 100-lead LQFP device – both shown twice actual size for clarity. You can see why the fine-pitch devices can't be soldered manually or even by wave soldering.

The real problem arises when it comes to devices with lead pitches of 0.4mm or 0.5mm, like the 100-lead LQFP device shown in Fig.4. These packages are not even suitable for automated wave soldering, let alone manual soldering. The leads and gaps between them are just too narrow.

Reflow profile

The only way to solder these devices is by reflow soldering. This process involves applying solder paste to all of the tiny copper pads on the board (using a laser-cut stencil and squeegee system), then placing the SMDs accurately in position on the board. Once the SMDs are in position, the boards are then placed on a conveyor belt and passed through an 'IR reflow oven' at a controlled rate, using infrared radiant heating.

Inside the oven, they move through areas with temperatures set for preheating, followed by a 'ramp up' to above the melting point of solder and then a 'ramp down' to well below the melting point. This is known as a 'reflow soldering profile'.

Using this approach, SMDs with a lead pitch of 0.4mm can be soldered to boards safely and with a high degree of reliability, at the same time as all of the other SMD components.

The main drawback is that a commercial IR reflow oven is very expensive (many thousands of pounds) and thus beyond the reach of enthusiasts and even many small manufacturers. Getting laser-cut solder paste stencils made from your PC board CAD file is not cheap either.

So, the challenge is to find a much cheaper way of soldering these fine-pitch SMDs on to PC boards. Fortunately, there is a way!

About solder paste

Solder paste is available from the better electronics stores. It consists of tiny spheres (<50μm in diameter) of tin-lead solder (63% tin, 37% lead), suspended in a water-soluble paste or gel of flux.

It's typically sold in fairly large plastic syringes, holding about 80 grams of solder paste. This is actually far too much for the average enthusiast, because the ingredients in the flux apparently have a shelf life of only six months after manufacture, even when stored in a refrigerator. Yet 80g of paste is enough to solder many hundreds – even thousands – of SMDs.

So, while solder paste is available, it's a pity that it isn't sold in much smaller quantities – say 5g or 10g, resulting in a lot less wastage.

When you buy solder paste, make sure you store it in a refrigerator so you'll at least maintain its six-month working life. Do *NOT* store it in a fridge that is also used to store food. If you must, place the syringe in an air-tight container, because both the solder spheres and the flux give off toxic fumes – see later.

Applying the paste

As mentioned earlier, large-scale manufacturers use laser-cut stencils and a squeegee system to apply just the right amount of solder paste to every pad on the PC board where an SMD lead or contact area is to be soldered.

This is shown in the upper two diagrams of Fig.5. This technique simply isn't practical for small manufacturers or enthusiasts.

A much simpler approach involves applying a thin 'stripe' of paste along the pads for the SMD leads, as shown in the lowest diagram in Fig.5.

The stripe of paste is only a millimetre or so wide and can be applied using a fine brush, a very narrow roller applicator or a fine spatula with a 1mm wide tip.

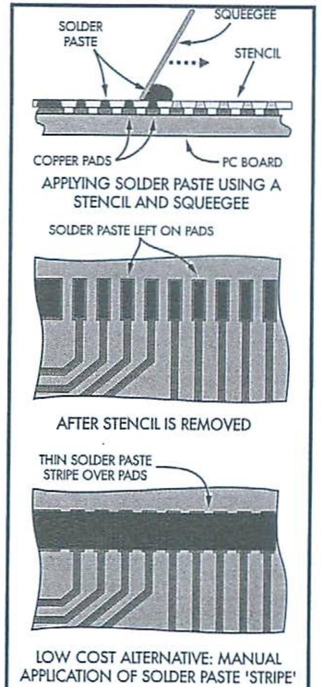
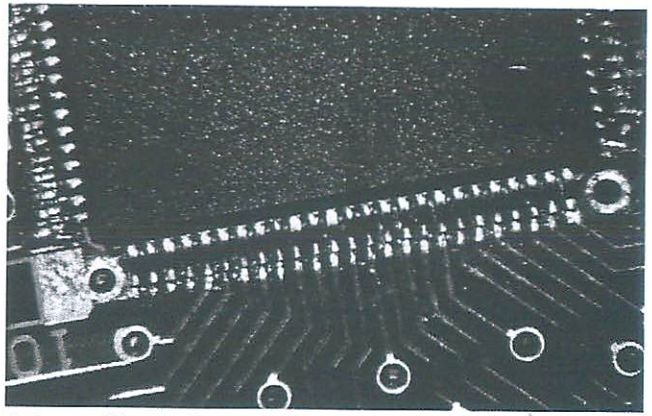


Fig.5: for reflow soldering, large-scale manufacturers apply solder paste to the board pads using a squeegee and a very thin stencil, laser cut from the PC board CAD file (top). This leaves the paste neatly on the pads (centre) but this is not feasible for enthusiasts. However, for fine-pitch SMDs, a very thin paste stripe (bottom) is almost as good.

Above: a close-up view showing a thin 'stripe' of solder paste applied manually to the pads for one side of a 100-lead LQFP device, with the tiny solder spheres just visible. This stripe is a tad uneven in thickness – a little too thick near the left end, and a little too thin towards the centre.



A close-up of the same board after the device had been reflow soldered using a snack oven. Despite the 0.5mm lead pitch, there were no solder bridges.

You'd think that applying a continuous stripe of solder paste in this way would be asking for trouble because it would form bridges between pads, during the reflow soldering process. However, the secret of this approach is to make the paste stripe very THIN – only about 100μm wide or two solder spheres thick.

If it's no thicker than this, the result is that surface tension and capillary action cause the solder spheres to 'pull themselves together' into the gaps between each SMD lead and its board pad, when they melt during the reflow soldering. As a result, most of the solder spheres in the paste between the pads get sucked into the molten solder directly under each SMD lead, leaving very few to form bridges.

Not too thick, not too thin

If you make the paste stripe too thick, there WILL be enough spheres left in the gaps between pads to form bridges.

On the other hand, if you make the stripe too thin, there will be insufficient spheres to pull together and form a good bond between each SMD lead and its pad underneath. So, erring in this direction results in 'missing joints' after the reflow soldering process – not at all easy to repair!

The most important thing about this manual approach to applying the solder paste is to take your time and to make the stripe width as you can. It's easiest to do this with the board under a magnifier lamp or even a low-power stereo microscope with illumination.

I've also found that a very thin and narrow-tipped (about 1mm) spatula seems to make it easier to apply and even-up the paste stripe, although a very narrow 'applicator wheel' (I made one myself) was almost as good and much easier than a fine brush.

Whatever you use, the main ingredient is time and patience – applying solder paste is a bit like trying to spread microscopic caviar evenly on a sheet of glass.

In fact, since you have plenty of paste, do a few dry runs on a sheet of PCB copper laminate.

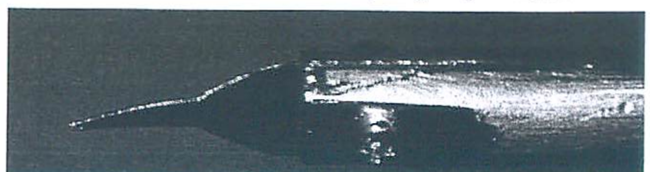
Placing the SMDs

Once the solder paste has been applied to the board, you can place your fine-pitch SMD(s) in position, with their leads over the board pads, ready for the reflow soldering process.

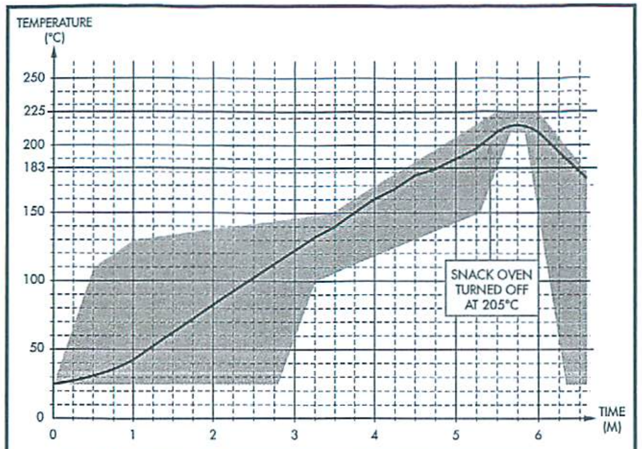
Large-scale manufacturers use a pick and place machine to position all of the components on the board in one pass – not just the fine-pitch SMDs, but everything else as well. Then all parts can be soldered to the board in a single pass through the reflow oven. But that's not really feasible if you're placing all of your components manually.

Our method is to place the fine-pitch ICs on the board first, then do their reflow soldering. After the board cools down you can then inspect the results, and if all is well you can proceed to solder in the rest of the components one by one, using the fine-tipped soldering iron approach illustrated in Fig.2 and Fig.3.

You may be wondering how accurately you have to place the fine-pitch IC packages in position, before reflow



The business end of a 'mini spatula' made by the author for applying a stripe of solder paste on pads for fine pitch SMDs. It's shown here about 3× actual size.



NOTES: SHADED PINK AREA SHOWS RECOMMENDED TEMPERATURE PROFILE LIMITS
183°C = MELTING POINT OF TIN-LEAD SOLDER (60/40)
225°C = RECOMMENDED PEAK REFLOW PACKAGE TEMPERATURE
BLACK CURVE = MEASURED TEMP PLOT OF BOARD & ICS
ON 220 x 140mm x 4mm THICK ALUMINIUM PLATE, HEATED INSIDE KAMBROOK
650W KOT-150 SNACK OVEN ('BAKE' SETTING, USING BOTH ELEMENTS)

Fig.6: the shaded pink area shows the reflow soldering temperature profile limits recommended by SMD manufacturers. The solid black curve shows the measured temperature plot achieved using a low-cost snack oven set on 'Bake'.

soldering. The answer is placed fairly accurately, but not fanatically so. The main thing is to make sure that every device lead is over its corresponding PC board pad and closer to that pad than it is to any other pads nearby.

If you achieve that, when the solder spheres in the paste melt and coagulate during the reflow process, surface tension and capillary forces in the molten solder will automatically 'pull' all the leads centrally into position over their pads.

So, the idea is to carefully lower the IC package (orientated correctly, of course) into position using a 'vacuum pick-up tool' or similar, and then nudge it gently into the correct position using a fine jeweller's screwdriver or pick tool. Again, it's easiest to do this under a magnifier lamp or stereo microscope, preferably one where you can rotate the board and IC until you're happy that all leads are over their pads on the board.

Once all the fine-pitch SMDs have been placed carefully in this way, your board will be ready for reflow soldering. Be very careful not to bump or jar it, because the SMDs could easily be jolted out of position.

Reflow soldering

Now, how do we do the actual reflow soldering? If you use an online search engine to track down info on reflow soldering, you'll find that quite a few people have tried doing it with an electric frypan or skillet.

The basic idea is to place the PC board in the centre of the frypan, applying power until the solder paste clearly melts and flows under each SMD lead. You then turn off the power and allow it all to cool down.

This can work – but there is a big risk of scorching the underside of the PC board; inevitably the underside of the board must be raised to a temperature considerably higher than the melting point of solder.

This board-overheating problem tends to be made worse because the heating element in the underside of most frypans is circular in shape. This produces uneven heating of the PC board, with a cooler region in the centre, surrounded by a ring of heat.

So, depending on the location of your fine-pitch SMDs on the board, the reflow operation can easily result in a ring of scorching on the underside of the board. The result is a totally unusable board, and the SMDs won't be salvageable either.

Get an old frypan

If you decide to try the frypan approach, ***please don't use a frypan that is also used for cooking food.***

The fumes given off by solder paste during the reflow process are quite toxic and are likely to be absorbed by the frypan metalwork and/or Teflon coating. So the toxins may well be transferred into any food cooked in the frypan afterwards.

Buy a cheap frypan specifically for the job, and mark it clearly **'NOT TO BE USED FOR COOKING FOOD'.**

Because of the toxic fumes given off during reflow soldering, it's also very desirable to do it in a well-ventilated area – preferably outdoors. This applies regardless of whether you use a frypan or some other heating device.

Having read the references on the web about reflow soldering using a frypan, I decided to try it, but with a slightly different approach.

I bought a cheap frypan, then did a few experiments with it. To try getting around the board scorching problem, I cut a 'heat spreader' plate from 4mm thick aluminium sheet and placed this in the centre of the frypan with my test board sitting on it.

This did seem to make the heating fairly even, but there was still a major problem. Even with the frypan's thermostat set for maximum, the temperature on the top of the PC board never reached the melting point of solder (183°C), let alone the 215° level that is necessary to ensure good reflow.

Presumably, the small air gap between the bottom of the frypan and my spreader plate added too much thermal resistance. I removed the spreader plate and tried again, with the board placed directly on the bottom of the frypan.

This time the temperature on the top of the board did reach about 210°C and reflow took place. However, when it had cooled down, I noticed that the underside of the board had been scorched in areas that had been directly over the circular heating element.

So, reflow soldering with a frypan is just not worth the risk of PCB damage.

In the oven

Another 'cheapo' reflow technique that you'll come across on the web involves the use of a small electric 'snack' or toaster oven. Almost all these use a pair of heating elements, one at the top of the oven compartment and the other at the bottom.

Whatever you're going to heat up in the oven goes on a tray supported by a wire mesh 'drawer' in the centre, which is linked to the oven door so it slides in or out when the door is closed or opened.

Often, there's a switch which allows you to select either the top element (Grill) or the bottom element (Reheat) or both at the same time (Bake). Each element draws about 325W, so the oven uses about 650W when both are used together. Since the reflow operation only involves drawing this power for five or six minutes at most, this isn't a problem.

The main advantage of using this kind of snack oven for reflow soldering is that the heating is done by infrared radiation, on the top of the board as well as from below, just like a 'proper' IR reflow oven. The main difference is that your board stays fixed in the oven during the whole process, rather than moving through different temperature regions on a conveyor belt.

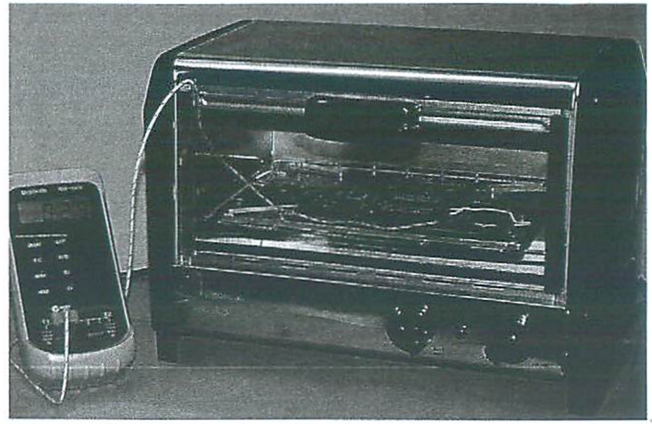
This means that you have to arrange for the reflow temperature profile to be provided in some other way. This turns out to be easier than you would think.

I decided to try the snack oven approach for myself, so I bought a Kambrook KOT-150 snack oven which cost just £20. It has no thermostat – just an electromechanical timer and the element selector switch. But the lack of a thermostat is not a problem, and the timer didn't turn out to be all that necessary either.

First bake

My first test with the snack oven was to clamp a thermocouple temperature probe onto a test board, which was then placed in the small pressed tinplate tray that came with the oven. The tray was then placed on the oven's sliding mesh drawer and the oven door closed carefully so that the thermocouple lead could exit through a small gap at the top of the door.

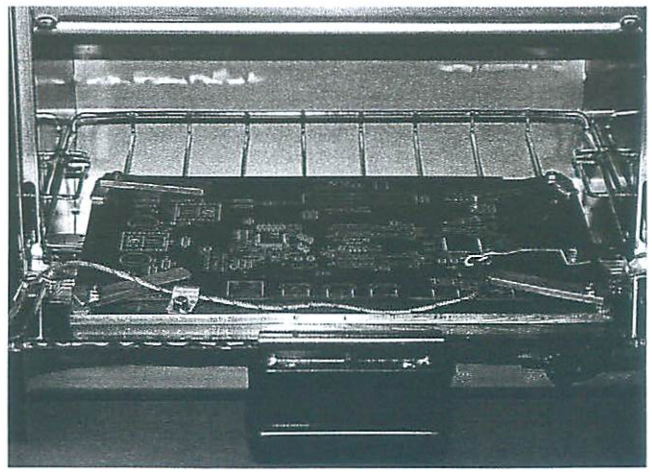
The oven was set to 'bake' (both elements on) and the timer knob set to apply power for about 10 minutes. I then proceeded to take temperature measurements every 15 seconds.



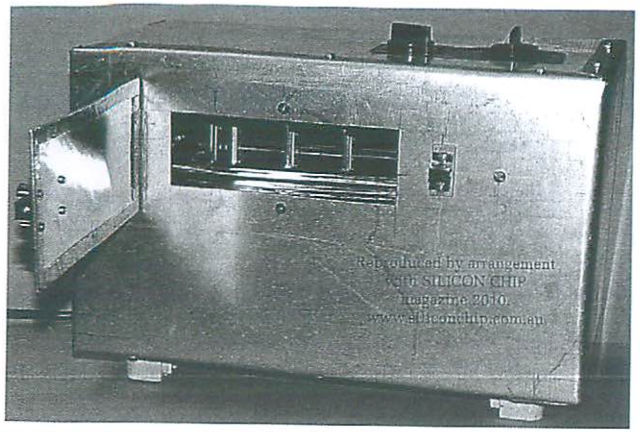
Here's the setup we used to successfully reflow solder fine-pitch SMDs. The board assembly is clamped on a 220 × 140mm plate of 4mm-thick aluminium plate, with a thermocouple probe clamped to the board copper near the 100-lead device. Shortly after this shot was taken the snack oven was turned on and then turned off as soon as the digital thermometer reading hit 205°C.

The resulting temperature characteristic turned out to be very close to the solid black curve in Fig.6, which also shows (shaded pink area) the reflow temperature profile limits for fine-pitch SMD IC packages recommended by chip manufacturers like NXP/Philips.

As you can see, the warm-up characteristic is nicely within the recommended limits. By turning off the power to the oven when the temperature on the top of the board just reached 205°C, the board temperature coasted up nicely to a peak of 215°C and then began to coast down again. It



As soon as the temperature coasted down to about 165°C, the door of the snack oven was carefully swung down to allow the entry of more air to speed up the cooling. Both SMDs on this board had been reflow soldered very nicely, with no solder bridges between leads or pads. The board had not been damaged in any way either, so we can recommend the snack oven approach.



It's not elegant but it works: an SMD chip baking oven, made by converting a discarded blower heater. The reflector part of the heater was flattened and bent into a small rectangular oven shape, then re-attached to the front of the blower heater element (just visible through the opened front door).

dropped down below the 183°C solder melting point temperature about 6.5 minutes after switch-on, so after waiting about one more minute, I carefully opened the door and drawer to allow cooling to occur more rapidly.

When the test board had cooled right down, I took it out of the tray and checked underneath to see if there had been any scorching. There was none at all – even the silk screen printing on the underside of the board showed no discolouration.

Trial run

Encouraged, I decided to carry out a reflow soldering test on another PC board. This was prepared with solder paste stripes around the pads for a fine-pitch IC, and then an SMD device was carefully placed over these pads. It was here I made my first mistake.

In an effort to make the process a little more controlled, I drilled four 3mm holes in the oven's tinplate tray, so the board could be fastened into it using four M3 machine screws and nuts. One of the screws was also used to attach the clamp for the thermocouple probe, to hold the probe securely in position with its bead in contact with the board's top copper close to the SMD chip.

The board and tray were carefully placed on the oven's mesh drawer and the oven door gently closed so they slid smoothly inside. Then power was applied to the oven again and the top-of-board temperature was checked every 15 seconds as before.

All went well, with exactly the same temperature profile as before. But then, just as the temperature reached about 200°C (just before I would turn off the power), there was a 'ping' sound – apparently the tinplate tray had been under stress as a result of the board being bolted inside and the stress was relieved suddenly when the temperature reached 200°.

Having turned off the power as soon as the temperature reached 205°, I waited impatiently while the temperature peaked again and crept downwards once more. Once it had dropped to about 165°C I carefully opened the door, so the drawer and tray slid outwards.

Then I examined the SMD chip with a magnifying glass, only to discover that the stress relief 'ping' at 200°C had caused the SMD chip to be jolted out of position. The reflow soldering had actually occurred quite nicely but with the chip and its leads in the wrong position.

On the plate

However, the overall result still confirmed that the snack oven was quite suitable for reflow soldering. I decided to make a much sturdier PC board support plate, to replace the flimsy tinplate tray. The new plate was a 220 × 140mm rectangle of 4mm-thick aluminium plate and had a 3mm hole drilled near each corner, for the board hold-down clamp screws.

The holes were countersunk underneath so that countersink-head screws could be used to hold down the board, without producing bumps underneath the plate. This was to make sure that the plate and board could be moved smoothly on the oven's mesh drawer.

Another board was prepared with solder paste and a fine-pitch SMD chip placed carefully in position. Then the board was clamped to the top of the new support plate, the thermocouple probe fitted and the complete assembly placed inside the oven.

This time, everything went really well. There were no 'pings', the solder reflowed nicely, and when it all cooled down again, a board inspection showed that the SMD chip had settled itself in the correct position and was nicely soldered. And there were no solder bridges!

So, we are able to report that reflow soldering of fine-pitch SMD chips can be done successfully using a low-cost snack oven like the one shown in the pictures. Listed on the page opposite are the 10 important 'rules of thumb' when it comes to using a snack oven to reflow solder fine-pitch SMD chips. If you follow these rules carefully, success is almost guaranteed.

Finally, what about using a 'fan-forced' snack oven? *Not* a good idea! The fan could easily blow the SMDs out of position! *EPE*

Ten Tips for successful DIY reflow soldering of SMDs

1. Store your solder paste in a sealed container in a fridge, to prolong its useful life.
2. Take care to apply the solder paste in a 'stripe' along the centre of the SMD lead pads on the PC Board, with the stripe no more than about 1.5mm wide and (most important) very thin – no more than about 100μm or two solder spheres. As even in thickness as you can make it, also – no lumps or voids.
3. Use a small snack oven for reflow soldering. Clamp the PC board on the top of a flat heat diffusion support plate made from 4mm thick aluminium sheet, say 220mm × 140mm in size (to fit comfortably in the snack oven). Also monitor the temperature on the top of the board near one of the SMDs, using a thermocouple probe connected to a digital thermometer.
4. Place the SMD chip(s) in position on the board carefully, with all leads as near as possible to their corresponding board pad. You don't have to be fanatical about this though: the chips will auto-locate during reflow, providing each lead is closer to its own correct pad than to the pads on either side.
5. Place the board and its support plate on the oven's slide-out drawer very carefully, so as not to bump or jolt the SMDs from their positions. Then carefully close the oven door so they slide smoothly into the oven – again without jarring.
6. Use both the upper and lower heating elements of the oven for reflow solder heating. This is usually achieved by selecting the Bake setting. Using both elements gives more even heating, closer to that in a proper IR relow oven.
7. Switch on the oven, monitoring the temperature on the top of board using the thermocouple probe and digital thermometer. The temperature should rise fairly smoothly, reaching the melting point of tim/lead solder (183°C) in just under five minutes. Take care not to bump or jar the oven after this.
8. As soon as the temperature reaches about 205°C, turn off the oven power without bumping anything. The temperature will continue rising, to reach a peak at around 215°C to 220°C. It should then begin falling again.
9. Wait until the temperature drops below the melting point of solder – say down to about 165°C. Then it should be safe to open the oven door so the drawer and its contents slides out, to speed up further cooling.
10. When the board has cooled down to around room temperature, remove it from the support plate and check the solder joints on all SMD leads with an illuminated magnifier or stereo microscope. If there are any solder bridges, these can be cut away using the tip of a hobby knife or 'sucked' off using desoldering braid and a fine-tipped soldering iron.

Footnote: About MSL Rating

If you're going to be using reflow soldering for SMDs in plastic packages, you should know a bit about the way these devices are rated in terms of MSL or 'moisture sensitivity level'.

Basically, it has been discovered that SMDs in plastic packages have a tendency to absorb moisture when they're stored in typical 'shop floor' or workshop conditions for any significant period of time. The degree of moisture absorption depends on a variety of factors – including the size of the device package, the number of leads and the relative humidity level in the storage environment.

The problem is, that when SMDs are heated up during reflow soldering, this absorbed moisture tends to turn into steam and build up sufficient pressure to cause cracking and other damage inside the package. It can easily damage the chip inside and/or its bonding wires, even if no cracks are visible on the outside of the package.

To minimise the risk of this kind of damage during reflow soldering, chip manufacturers nowadays bake most plastic-package SMDs (especially those in fine-pitch packages) for many hours at 125°C in a very dry and inert atmosphere, to drive out any moisture. Then they are sealed in hermetic packaging (dry packs) and the idea is that they should be left in this packaging until just before they're subjected to reflow soldering.

Now, because this last-minute unpacking isn't practical, even for big manufacturers, and in any case isn't really necessary for some devices, semiconductor industry standards bodies like JEDEC (formerly the Joint Electron Device Engineering Council) have established a system whereby each device is given a rating to show how long it can be safely left out of its hermetic packaging in a typical 30°C/60%RH workshop or factory environment, before reflow soldering. There are eight of these MSL rating levels, ranging from MSL 1 for packages which are deemed impervious to moisture, up to MSL 6 for packages which are very sensitive to moisture and must be reflow soldered within no more than six hours after being removed from their dry packs.

You'll find this MSL rating printed on the dry packs of most SMD devices in plastic packages, and certainly for those in fine-pitch packages (which are almost always rated at MSL 2 or higher). The table below shows the significance of the various MSL levels.

So, what do you do if you want to reflow solder an SMD with an MSL level of 2 or higher, and you know it has been out of its hermetic packaging for longer than its rated safe time? Alternatively, what if it hasn't been out for that long, but has been subjected to very high relative humidity?

The good news is that it can be restored so that it can be safely reflow soldered by baking for about 24 hours at a controlled temperature of between 115°C to 125°C. This can be done in a small fan-driven hot-air oven, provided the device is placed in a small metal box to ensure even heating. The box should also have some small vents to allow the escape of any moisture that is released during the baking.

I made up a small baking oven by converting a fan-type room heater that had been dumped at council clean-up time. The fan motor, fan and heating element were all in perfect working order, as was its thermostat switch.

So, all I had to do was remove these components and convert the heater case into a recirculating-air oven. Then the 'works' were reinstalled and the thermostat tweaked to cycle the oven temperature around 118°C, which produced a rough but quite serviceable DIY baking oven for plastic package SMDs.

JEDEC MOISTURE SENSITIVITY LEVEL (MSL) RATINGS

MSL rating	Safe exposure time at <= 30°C/60%RH before reflow soldering
1	Unlimited (non moisture sensitive)
2	1 year
2a	4 weeks
3	1 week (168 hours)
4	72 hours
5	48 hours
5a	24 hours
6	6 hours (extremely moisture sensitive)