# Lead-free? No p

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**The use of lead-containing solders will be severely restricted from the beginning of July 2006. This has far-reaching consequences, especially with regard to automated soldering.**

## We take a closer look.

Electronics is playing an ever-increasing role in all areas of daily life. As a consequence the number of discarded and redundant electronic appliances and components is continuously on the rise. The EU member states together generate over six million tonnes of electronic waste per year. Furthermore, many electronic and electrical appliances contain toxic substances such as lead, mercury and cadmium.

In 2002 the European Parliament and the Council of the European Union, representing the national governments, enacted two directives, 2002/95/EC and 2002/96/EC, which became known as 'RoHS' and 'WEEE' [1][2]. The directive on 'Waste Electrical and Electronic Equipment' puts liability on manufacturers to mark their appliances, to take old appliances back, recycle them as far as possible and prepare the residual waste for disposal [3].

The ban on the use of certain specified hazardous substances in the manufacture of new appliances will avoid damage to the environment and human health, and questions of disposal methods will arise. To this end the RoHS ('restriction on the use of certain hazardous substances in electrical and electronic equipment') regulations have been adopted, which restrict the use of specified hazardous substances. The regulations cover not only lead, which is an important constituent of solder and which is responsible to a large extent for its properties, but also mercury, cadmium and other substances used in such things as cables and enclosures. The various EU member states are transposing the directives into national law.

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# Soldering in the RoHS era


## The one part in one thousand limit

July 1st 2006 is a key date for developers and manufacturers of electronic equipment: this is when the ban on hazardous substances comes into effect. From this point it will no longer be permitted to bring 'onto the market' any electrical or electronic appliance which is not RoHS compliant, that is, which contains any of the proscribed substances. In order to make the purification and analysis of materials technically and economically feasible, thresholds have been set below which a material will be considered 'free' from a particular substance: for example, a solder containing less than 0.1 % lead by weight will be deemed 'lead-free' for the purposes of RoHS.
These thresholds apply for all 'homogeneous' materials from which an appliance might be constructed. ('Homogeneous' means that the material can only be further decomposed by chemical, rather than mechanical means.) Examples are the metal used for an enclosure, copper printed circuit board tracks, solder and so on. It is therefore necessary that not only the equipment, but also the boards and components used in it, are RoHS compliant. If, for example, the solder used contains more than the maximum permissible level of lead, the whole appliance may no longer legally be sold. Non-compliant components and printed circuit boards may, however, be used after 1 July 2006 as spare parts for, or for repairing appliances which were sold before the critical date. Lead-containing solders may also be used in servers and storage systems until 2010, as well as in various types of telecommunication equipment. There is also a comprehensive exemption for military equipment.

The regulations are principally aimed at the manufacturers of electrical and electronic devices, but inevitably all parties in the chain of production and sale are affected to some extent. New lead-free components and manufacturing processes must be made available. Those responsible for development and manufacture will have new challenges in coping with the regulations. End users, on the other hand, will see little change. Building a circuit or device purely for your own use does not constitute bringing it 'onto the market' and so in this case old components and lead-containing solders can still be used.

## Purchase and design

The RoHS directive has a double effect on the choice of components, since assembly houses and manufacturers may no longer use lead-containing solders, which have a particularly low melting point (183 °C). This means that, in general, higher soldering temperatures are necessary. Unfortunately it is not possible to deduce from the fact that a component is declared as 'RoHS compliant' that it can withstand higher soldering temperatures! RoHS compliance means only that, for example, the coating on the leads of a component is lead-free tin. Critical components include, for example, electrolytic capacitors, devices in BGA (ball grid array) packages, and SMD connectors. Caution should be exercised when purchasing new versions of components. More on this problem can be found on distributors' websites [4][5][6] (see **Figure 1**).

In a mass production environment a complete changeover for all component types in a single step is thought to be the best way to proceed. This of course demands considerable research into new components, redesigns and experimentation with soldering processes. In this regard it is possible to learn from the experiences of others through the formation of industrial associations and groups. The ZVEI (Central Association of the German Electrical and Electronic Engineering Industry) has published a guide to lead-free soldering, available on the Internet as a free download [7].


**Figure 1.** Many component distributors have set up special RoHS pages.

**Figure 2.** The formation of solder bridges can be avoided by the use of an inert atmosphere.

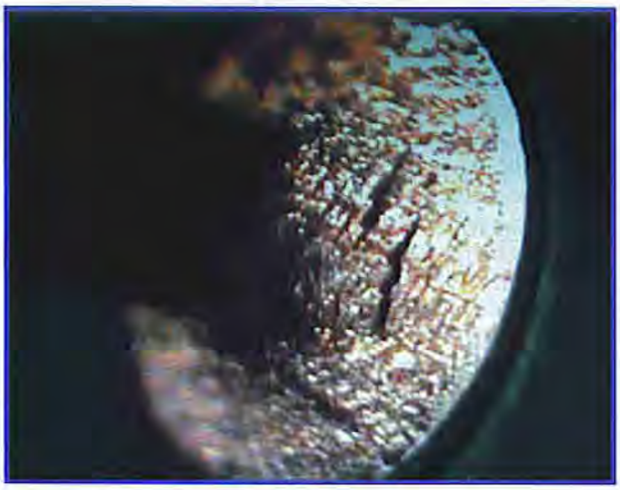


**Figure 3.** The porous appearance of the surface of a lead-free soldered joint may seem odd at first.

In general significant changes to printed circuit board layout, such as increasing the size of solder pads and increasing the distances between copper areas, are not required. Larger components and larger tracks must however be provided with thermal pads for optimal soldering.

## Wave soldering

In industry through-hole (TH) components are most frequently soldered using a wave soldering process. Here the printed circuit board is passed over a solder bath in which a wave is created using nozzles.
If it is not desired to completely replace soldering equipment in the switchover to a lead-free process, modifications will be required to existing equipment. The reservoir and pump systems in new equipment are already supplied with surfaces coated so that they are capable of withstanding the more aggressive lead-free alloys; older equipment must be likewise modified.

When lead is substituted by other metals with a higher melting point, the soldering temperature must increase. Whereas until now temperatures of around 230 °C have been adequate, solder baths must now run at temperatures of up to 260 °C. In general the preheat temperature now plays a more important role: large components, with their higher heat capacity, must be checked and adequately heated in order to avoid failure or damage.

There is a plethora of solder alloys available on the market. In general a SnAgCu (tin-silver-copper) alloy, with a melting point of 217 °C, is the most popular and there is already plenty of experience with it. It avoids problems such as whisker formation which can occur with pure tin alloys. These whiskers are threads of solder forming from the soldered points which can unfortunately cause unwanted short circuits.

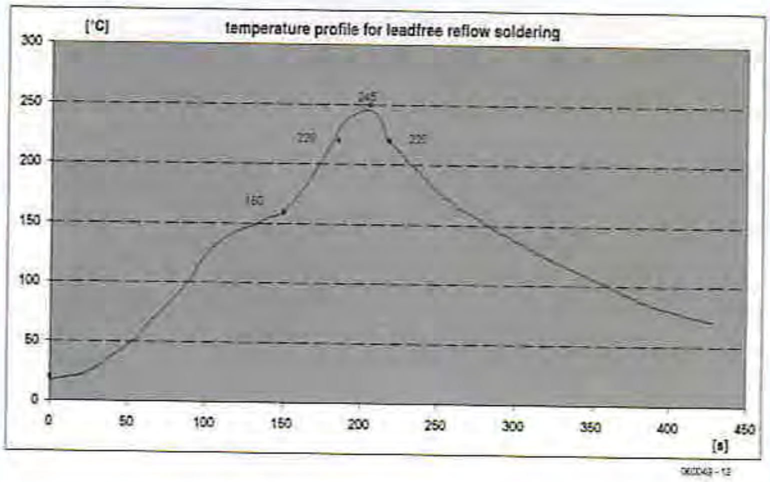
When using lead-free alloys the contents of the solder bath must be continuously monitored by taking samples, since there is a tendency for the proportion of copper to increase. When this reaches a critical level the solder can flow too readily, leading to unsatisfactory results. Depending to the results of the tests, it is possible to add tin-silver alloy, pure tin, or tin-silver-copper alloy to the solder in the bath.

## Reflow soldering

As in the case of wave soldering, reflow ovens (see box) also require modification or replacement by new equipment. The modifications generally include a powerful heater system and improved thermal insulation, in accordance with the higher temperatures involved in the process. Solder bridges must be watched out for: these arise from increased oxidation of the solder and can be prevented by the use of an inert atmosphere (see **Figure 2**). In mass production the use of an inert atmosphere is essential.

The established manufacturers offer a selection of lead-free solder pastes. When experimenting it is possible to use a standard lead-free solder temperature profile, which will, as a rule, give good results for 90 % of components. The number of available temperature profiles can be rather large, depending to a significant extent on the product range.

# Reflow soldering




Although most 'normal' SMD components can still be soldered manually using a fine soldering iron bit and fine solder, components in BGA, CSP (chip scale package) and similar packages can still only be soldered by machine. The so-called reflow process is a reliable method. In this process a solder paste is spread onto the pads on the printed circuit board where the component will sit: the paste can of course be lead-free. The components are then placed on the printed circuit board so that their connections are embedded into the paste. The connections can now be soldered in a reflow oven. This process takes place in five precisely-controlled steps, called 'phases' (phase 1 to phase 5 in the figure above).

Phase 1 is called the 'preheat phase'. The temperature in the reflow oven is gradually increased to approximately 125 °C. The temperature must rise slowly, as otherwise bubbles can form in the solder paste. Phase 2 is the 'soak phase', or 'activation phase'. Here the temperature is very slowly increased to approximately 175 °C. During this phase the solder paste is activated; the flux changes into its liquid state and flows over the pads.

Once the circuit board and components are 'soaked', phase 3, the 'reflow phase', is entered. The temperature rises relatively quickly to above the melting point of the tin in the paste so that it melts, and the actual soldering takes place. With lead-containing solders the target temperature is about 220 °C to 240 °C; with lead-free solders it must be increased to between 250 °C and 260 °C. In phase 4, the so-called 'dwell phase', the soldering temperature is held constant for a few seconds. The tin particles held within the solder paste melt into one another and displace the other components of the paste. Between the component connections and the pads on the printed circuit board there is now only molten tin, which binds them together. After 15 s to 20 s of dwell, phase 5, the 'cooling phase', is entered and the populated board is gradually cooled to room temperature.

## Hand soldering

For repairs and hand soldering the switchover will be straightforward: simply turn up the temperature on the soldering station. Lead-free solders corrode the bit more rapidly, although service companies have reported no significant increase in their use of soldering iron bits. Nevertheless, some manufacturers have brought out new products, such as soldering iron bits made of silver to improve heat conduction. In some cases, such as when a circuit board conducts heat away too rapidly, it is possible to obtain better results by providing additional heating using hot air.

Lead-free soldering takes a little getting used to. The joints are not as bright as those made using lead-containing solder and have a porous surface appearance (**Figure 3**). Lacking lead, the joints are thicker and harder and have a different shape (**Figure 4**). A joint that has what would have been an unsatisfactory appearance is thus likely to be perfectly good. This calls for new guidelines for the quality control of soldered joints, as laid down in the paper 'IPC A-610D' by the IPC (formerly the Institute of Interconnecting and Packaging Electronic Circuits) [8].

## Outlook

In the medium term the need for two sets of component stores and two sets of soldering stations will disappear. Niche companies will be set up alongside existing in-house manufacturers and electronics servicing companies, offering repair facilities as well as materials and manufacturing capacity for appliances falling outside the regulations.

For hobbyists the switchover to a lead-free regime means access to a wide range of new solders, fluxes and components. At the same time a wide range of lead-containing materials will disappear from the market. It is

**Figure 4.** Because of the lack of lead, the shape of the joint is different.

## The Elektor Electronics SMD Reflow Soldering Oven

Here at the Elektor Electronics laboratories theory and practice go hand in hand. When we had to solder an FPGA in a BGA package [9], we realised that we needed a reflow oven. Rather than ordering an expensive device, the Elektor Electronics designers had a clever idea: convert their beloved pizza oven into a reflow oven. The team developed a temperature controller circuit based around an AT89C52 microcontroller. Of course, we did not keep the idea a secret from our readers [10]: the 'SMD Reflow Soldering Oven' project by Paul Goossens, published in the January 2006 issue, generated enormous interest, as evinced by the dozens of reader letters and e-mails we received. There were many questions about reflow soldering and about our oven design in particular, and many interesting modifications were proposed. One UK reader has even converted his toaster into an SMD soldering oven [11]!

It is easy to alter the temperature profile in the controller to suit lead-free soldering using the 'EDIT' function in the microcontroller program: a good starting point is the set of values given in the box 'Reflow soldering', but this is no substitute for a careful study of device datasheets.

expected, however, that in the short to medium term availability of lead-containing components will remain good, since residual stock will come on to the market.

About the author: Felix Meckmann is marketing manager at Schlafhorst Electronics GmbH. The focus of operations for this firm, based in Germany, is the contract development and manufacture of electronic modules, products and systems. With 130 staff, the company has been making a positive commitment to lead-free technologies since the beginning of 2004. As well as an SMT production line, wave soldering and selective lead-free soldering are available. The company has to date delivered 200,000 RoHS-compliant modules.

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## Links


[1] www.europa.eu.int/scadplus/leg/en/lvb/l21210.htm

[2] http://europa.eu.int/comm/environment/waste/pdf/faq_weee.pdf

[3] Elektor Electronics, January 2006, p. 22 and www.elektor-electronics.co.uk/Default.aspx?tabid=27&year=2006&month=1




[4] http://uk.farnell.com/static/en/rohs/

[5] http://rswww.com/

[6] www.arrow.com/green/

[7] www.zvei.org/fileadmin/user_upload/Technik_Umwelt/Elektro_Elektronikaltgeraete/Bleifrei/Leitfaden/Lf-Blei-EN.pdf

[8] www.leadfree.org

[9] Elektor Electronics, March 2006, p. 16 and www.elektor-electronics.co.uk/Default.aspx?tabid=27&year=2006&month=3

[10] Elektor Electronics, January 2006, p. 28 and www.elektor-electronics.co.uk/Default.aspx?tabid=27&year=2006&month=1

[11] Elektor Electronics online Forum, www.elektor-electronics.co.uk/default.aspx?tabid=29&forumid=16&postid=697&view=topic