



Semiconductors

Leading the way to Pb-free packaging

PHILIPS

Solving the Plumbum (Pb) conundrum

Used in ancient times, lead (or 'Plumbum', Pb, in Latin) is a metal with a long application history. In fact, the word 'plumber' is derived from the Roman use of lead pipes for carrying water. However, when absorbed by the human body, lead is a cumulative poison detrimentally affecting health in several ways. And in children, lead can impede brain development, making them particularly vulnerable to lead poisoning.

Today, lead piping is obsolete and the largest use of lead is in car batteries. But some semiconductor packages and solders used in electronic circuit boards do contain lead. Though these are small quantities, the sheer volume of electronic consumer goods produced today means there is a risk of lead contaminating drinking water¹⁾²⁾, plants and animals – for example, by acid rain filtering through landfill sites – and that is a concern to all of us.

Recycling and careful disposal go some way to addressing the lead health hazard but at Philips, we believe prevention is better than cure, i.e. making the manufacturing process Pb-free. We are actively engaged in researching new soldering materials, processes and package-terminal platings with the aim of making our broad product portfolio completely Pb-free in the near future. And in some products, such as the majority of our DIP, SIL and QFN packages, we've been Pb-free for many years.

As a global company committed to environmental care, we cooperate with leading suppliers and customers on a wide range of 'green' issues. It's a commitment we take seriously, so it's not surprising that the first factory in the world to receive ISO 14001 certification was one of ours.

Moreover, our Eco Vision program and Eco-Design philosophy ensure that better products and more environmentally-friendly manufacturing processes lie ahead. And that includes both Pb- and halogen-free products.

'Profitable green' is the name given to Philips Semiconductors' approach to environmental issues. We aim to reduce the environmental impact of our products while providing customers with leading-edge technology at the lowest possible cost. One example of this is our 'green' plastic packaging. Used in all our new LQFP and TQFP packages, this plastic significantly increases product lifetimes at high temperatures, yet it does not contain brominated flame-retardants. Likewise, on the road to a Pb-free future, Philips Semiconductors is leading the way.

The need to be Pb-free

Throughout the electronics industry, the desire for Pb-free electronics is a hot topic. Customers and manufacturers alike are keen to ensure that new regulations in Europe, the US and Far East are complied with, sooner rather than later:

- In Europe, an EU directive on Restrictions on the use of Hazardous Substances (RoHS) includes a requirement to eliminate Pb in electronics, in all but special applications, by July 1st, 2006
- In China, the government is working on bringing in similar legislation to the Europeans
- In Japan, electronic waste and recycling laws oblige manufacturers to eliminate or recover their waste products containing Pb
- In the United States, laws banning or restricting the use of Pb are coming for many products and there is an increasing demand for a total ban.

¹⁾ WEEE directive: "Proposal for a Directive of the European Parliament and the Council on waste electrical and electronic equipment, 2000/C 365 E/12.

²⁾ Nordic report: "Environmental Consequences of Incineration and Landfilling of Waste from Electr(on)ic Equipment", S-O Tabermann, B. Carlsson, H. Erichsen, J. B. Legarth and J. C. Gregersen, TeamaNord 1995:155, 1995.



The electronics industry is now focused on Pb-free assembly processes and the issues concerning the higher temperatures needed for both reflow and wave Pb-free soldering. By investing heavily in our own research organization, we have developed cost-effective Pb-free manufacturing processes that guarantee the reliability of our components. Moreover, we're being proactive in also looking into solutions for devices where Pb is contained inside the package: replacing Pb-based solders in some Multi-Chip Modules/SiPs with new glues, for example.

Tackling the issues

Understanding all the potential risks of going Pb-free is the key to ensuring our future success. By thoroughly addressing the following issues, we're confident that a Pb-free future is just around the corner:

- Forward compatibility – ensuring “old” products containing Pb still meet customers’ requirements and are compatible with both Pb-based and Pb-free solders/PCBs
- Backward compatibility – ensuring “new” Pb-free products can be used with Pb-based technologies

- Re-qualification of current products – updating the portfolio with standardized Pb-free solutions
- Device reliability – coping with higher temperatures in new Pb-free manufacturing/assembly processes³⁾, and ensuring solder-joint reliability using new materials.

Our strategy to expand our range of Pb-free packages comprises a thorough investigation to tackle all of the above issues, ensuring full compatibility with new soldering processes, and to implement Pb-free materials for the terminals and solder balls on all packages.

Pb-free soldering process

Based on current research, we advise using SnAg3.8Cu0.7 (SAC) eutectic solder for general-purpose applications. In wave soldering, this would entail a bath temperature of 260 °C and a contact time of about 3 seconds. Similar alloy would also be used for reflow soldering. Our temperature profile (see below) for testing products is based on the IPC/JEDEC joint industry standard: J-STD-020.

Package Thickness	Volume mm ³ <350	Volume mm ³ 350-2000
>1.6 mm	260 + 0 °C *	260 + 0 °C *
1.6 mm - 2.5 mm	260 + 0 °C *	250 + 0 °C *
≥2.5 mm	260 + 0 °C *	245 + 0 °C *

Table: Pb-free Process – Package Classification Reflow Temperatures

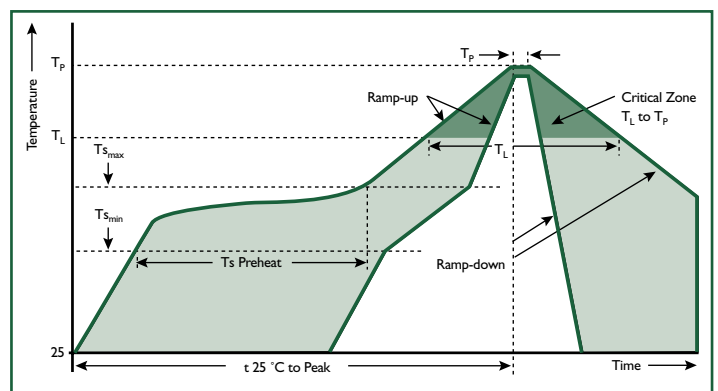


Figure: Classification Reflow Profile

³⁾ Higher temperature leads to increased risk for moisture-related fails. Proposed

Profile Feature	Pb-Free Assembly
Average Ramp-Up Rate ($T_{s_{max}}$ to T_p)	3°C/second max.
Preheat Temperature Min ($T_{s_{min}}$) Temperature Max ($T_{s_{max}}$) Temperature ($T_{s_{min}}$ to $T_{s_{max}}$)	150 °C 200 °C 60-180 sec
Time maintained above Temperature (T_L) Time (T_L)	217 °C 60-150 seconds
Peak/Classification Temperature (T_p)	See Table 4.2
Time within 5° C of actual Peak Temperature (T_p)	20-40 seconds
Ramp-Down Rate	6 °C/second max.
Time 25° C to Peak Temperature	8 minutes max.

Table: All temperatures refer to topside of the package, measured on the package body surface

Our current research indicates that higher soldering temperatures affect a number of surface mount devices. It is advised to keep the package top-body temperature at 245 °C max. Work continues to improve the resistivity of the products to high soldering temperatures. In addition, Philips Semiconductors is assessing mechanical stress and fracturing in ceramic and glass components – SAC is stronger than Pb-based solders.

Industry cooperation

Present soldering and plating technologies using Pb are well established throughout the semiconductor industry. Likewise, the procedures and standards for evaluating quality and reliability are recognized worldwide. With a large variety of new Pb-free technologies under investigation, Philips Semiconductors is working together with other leading manufacturers. This is to ensure the methodologies for measuring solderability, heat resistance and whiskering are consistent, to fairly assess all competing technologies.

For further details about this cooperation, please see our website at: http://www.semiconductors.philips.com/green_roadmap/documentation/index.html

Though our Pb-free technologies are based on our current research and experience, we are committed to high performance, quality and reliability, and we'll ensure that our products will continue to delight customers.

Pb-free terminals

With many years of experience in using pure tin to coat semiconductor package leads/terminals, we know that tin is the logical choice for a drop-in replacement for those devices currently using SnPb-alloy coatings. We have studied whiskering with tin finishes, focusing on the leads of surface-mount devices and the results proved successful. Extensive testing for all packages is now almost completed.



Pure Sn, NiPdAu and SAC offer a very compatible replacement for SnPb alloys and consequently they are our preferred solution. In exceptional circumstances when pure tin is not feasible, we will offer alternative alloys. For the contacts of Ball-Grid Arrays (BGAs), we selected SnAgCu alloy (SAC).

Roadmap

Philips Semiconductors will be fully compliant with new regulations by mid 2005 – well ahead of the European legislation. In fact, more than 95% of our through-hole packages (e.g. DIP, SIL) and over 50% of our surface mount packages (e.g. QFN, QFP) are already manufactured with Pb-free terminals. To check if an individual part is Pb free, go to our website: <http://www.philips.semiconductors.com> and enter a part number. For our roadmap overview see our lead-free web pages http://www.semiconductors.philips.com/green_roadmap/

Special product labeling will be used to identify Pb-free shipments. If space allows, individual products will be marked with a one-digit code, G, E or N. (G = Pb-free/green, E = RoHS allowable exemption and N = not-Pb-free). Part numbers will remain the same (except new BGA parts, because of their limited backward compatibility) since most customers want part numbers to be kept consistent. There are several reasons for this, such as planning and capacity considerations, the need to control old parts (and avoid stock that needs scrapping), and the desire to reduce the logistics consequences for the supply chain.

All new Pb-free products are backward production compatible (although only to a limited extent for BGAs) meaning that they can be used in both a Pb-free and a Pb-based soldering process, which simplifies the manufacturing choices.

Package Families	2001	2002	2003	2004	2005	2006
DIP, HDIP, SDIP			Sn			
SIL-MP SIL-P			Sn			
(H)(T)(S) SOP (H)(T)(L) QFP		SnPb			Sn	
Discrete Packages		SnPb			Sn	
QFN-SON			NiPdAu			

* Please note that the curves of the graph reflect the general transition excluding Pb allowed by exemptions (medical, telecom, etc)

Philips Semiconductors

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