Lead-Free Soldering In Automotive Applications

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The introduction of Lead-free soldering in the electronics industry has already started and nearly all products will be manufactured with this technology by mid-2006, as established by European legislation. However, this legislation does not cover automotive applications. In fact, before Lead-free technology can be used in all automotive applications, it is necessary to collect more information and conduct further testing. In particular, accelerated testing techniques have to be verified against actual long-term field data to make sure they yield meaningful results. Due to the particular operating environment of automotive electronics, this cannot be done in as a short time frame as for standard electronic devices. Therefore European legislation has only set a limit for Lead content in cars, but no total ban yet.

Environmental concerns have led to the establishment of legislation banning the use of Lead in electronic assemblies in Europe. A strict deadline has been set for mid-2006. From this date onwards, no new product on the market may contain Lead in any quantity. The electronics industry, particularly in Japan, has taken this opportunity to establish a line of "green" products.

The automotive industry is exempt from these regulations and has a legislation of its own. According to EU laws, there is a limit of 60g of Lead for all the electronic components in every car.

Difference between standard electronics and automotive applications

The demands on electronic equipment in cars are much higher than in other products. First of all, the electronics in a car are responsible for life saving functions like breaking and airbag deployment. The need to guarantee these functions is very strong.

Secondly, the operating environment is very different compared to standard electronics. The temperatures range from a minimum of -40°C to a maximum of +85°C. In addition, automotive electronic devices are subjected to continuous vibration, making the environment even harsher.

A roadmap for Lead-free in cars

It is not possible to switch from the well-known Lead-based soldering technology to a Lead-free technology without first gaining extensive field experience. Within the automotive supply chain, there is an ongoing discussion on how to handle this changeover while at the same time guaranteeing safe and stable functionality of automotive systems.

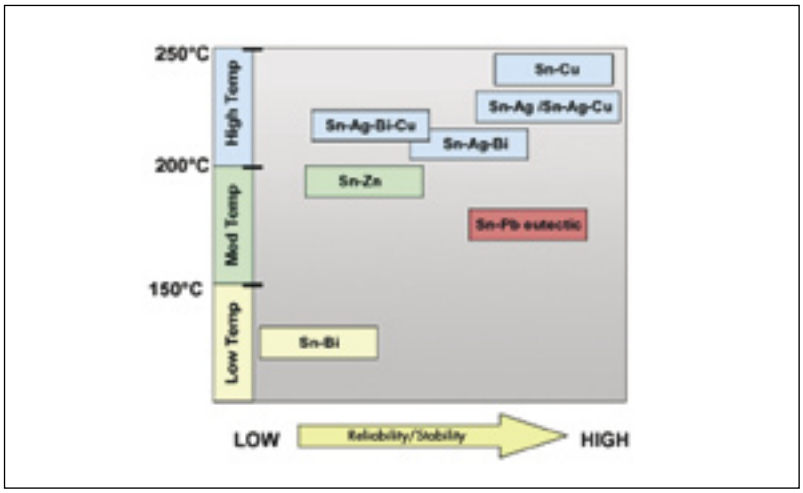
The introduction has to be done step by step, according to the following procedure:

A) Development of Lead-free technology
B) General qualification
C) Introduction of a number of dedicated Lead-free products
D) Qualification for these products
E) Acquisition of experience with Lead-free in the field
F) Analysis of the results
G) Definition of corrective actions for design and production
H) Switch to 100% Lead-free products.

The steps from A to C could be taken as the procedure for standard electronics products. Steps D to H are necessary to acquire the field experience with Lead-free devices and are specially important for automotive products. These additional steps will require a certain amount of time.

In the German automotive industry, a working group has been established to look into the so-

Figure 1: Illustration of the alternatives in Lead-free technology



lutions for Lead-free technology as well as to establish how long it will take to make the complete switch to Lead-free. Members in this working group are:

- Audi, BMW and Daimler-Chrysler (Car manufacturers)
- Bosch, Hella and SiemensVDO (Electronics manufacturers)
- Schweizer electronics (Printed circuit board supplier)
- FNE (Solder materials supplier)
- RMCtech (Consulting).

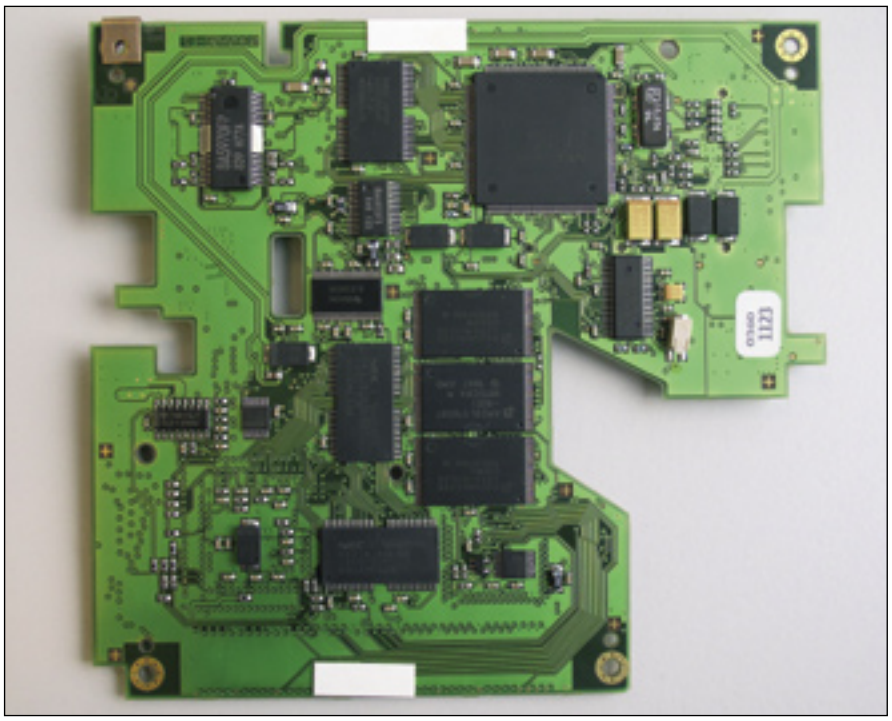


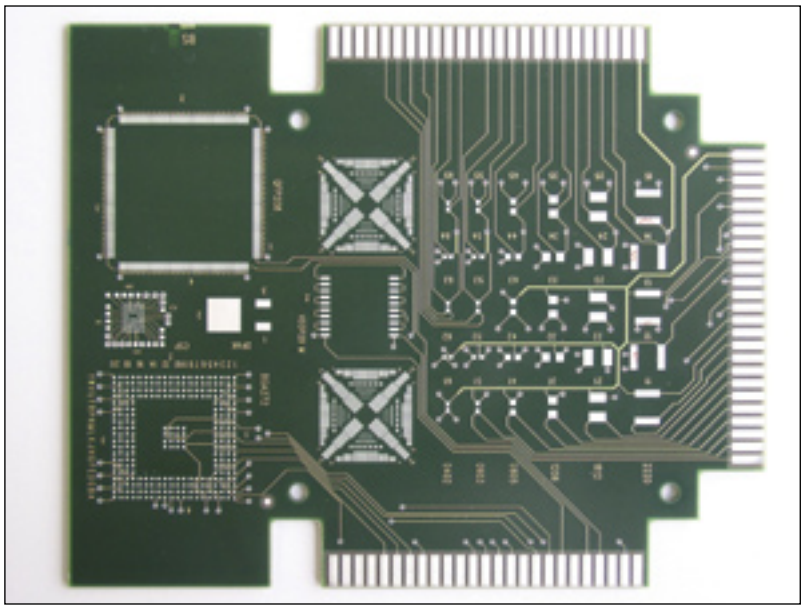
Figure 3 - Actual product; size 130 x 120mm

To establish this roadmap, it is also necessary to take into account the complete life cycle of a car design. From the initial concept, through the development phase to the start of volume production until finally the last car rolls off the assembly line, there are typically more than eight years of time. Consequently, it is not possible to switch to Lead-free production before at least this time span has elapsed. In the discussion, it was given that a change to Lead-free components when a car is already in production is not feasible because of the unsustainable economic impact. This means that for the last production line to switch to Lead-free electronics, it will take roughly until the year 2014.

Technical solutions

The non-automotive electronics industry is deeply involved in making the changeover to Lead free technology. In many research projects and in many working groups around the world, the technological possibilities have been developed and the reliability of the different solutions is now well-known.

Figure 2 - Test PCB for testing the behaviour of Lead-free components; single side assembly; size 140x115mm



The main difference in Lead-free electronics production will be the use of a new type of soldering material. In Table 1 and Figure 1 some of the most popular Lead-free soldering materials are listed.

Among the most promising soldering materials today are the two alloys SnCu and SnAgCu. On the other hand the surface conditions of both the components and the printed circuit board have been changed as well. Some of the most commonly used materials for surfaces are pure Sn, Ni/Pd/(Au), Ag, Sn/Cu.

What material is used depends on the component type and the manufacturer, so currently, many different materials are in use and the electronics manufacturers must deal with a mix of these different alloys.

Composition	Solidus [°C]	Liquidus [°C]	U.S. Patent
SnAg3,8Cu0,7	217-218	Eutectic	No
SnAg4,0Cu0,5	217-218	Eutectic	No
SnAg3,9Cu0,6	217-218	Eutectic	No
SnAg3,4Bi4,8	211	213	Yes
SnAg3,5	221	Eutectic	No
SnAg2,5Cu0,8Sb0,5	215	217	Yes
SnCu0,7	227	Eutectic	No
SnSb1,0	232	235	No
Sn63Pb37	183	Eutectic	No

Table 1- Some of the most popular Lead-free soldering alloys

Lead-free production

Commercial

The use of soldering materials with higher melting temperatures leads directly to higher soldering temperatures. For reflow soldering the temperature will rise from 235°C to 245°C. For wave soldering the temperature will increase from 260°C to 280°C. Clearly, with the increase in reflow temperature, the demands on components and equipment in terms of temperature resistance will also increase.

By now, the Lead-free versions of many standard types of electronic components are available on the market. Most manufactures have the tendency to switch over to Lead-free technology as soon as they have both technologies ready for production. The use of both technologies in parallel, however, is not the preferred strategy. It is foreseen, that all standard components will be available for Lead-free processing by the end of 2005. Therefore all electronics manufacturers will have make the change at this time.

Soldering machines also have to be changed. The requirement for Oxygen-free technology seems to be one of the key factors of Lead-free soldering technology. Also, more stable temperature control was another challenge that had to be faced by equipment manufacturers. Today soldering machines have reached a satisfactory level in this respect.

Finally, solder joint inspection methods also have to be changed when switching to Lead-free production. The appearance of these joints is totally different compared to Lead containing joints. Therefore it is necessary to collect more data in order to establish more precise evaluation parameters for their inspection.

Automotive electronics

The working group mentioned above discussed how to handle the requirement of not having more than 60g of Lead per vehicle. For this purpose various electronic circuits were chosen, from powertrain and infotainment to chassis and safety devices, which represented the different types of electronics used in cars today. The manufacturers of the boards had to determine the Lead content of each in order to calculate the total Lead content for different types of cars.

Passing on to the next step in the changeover to Lead-free automotive electronics (see point C in the above-mentioned procedure), it was necessary to select the first electronic devices for the switch. In preparation for this step, it was found that only 80% of component types are available in Lead-free technology today. The reason is the demand for special automotive components. One example of such a component is the extremely high capacitance capacitor used for protecting circuits in the power supply line. This type of component cannot withstand the high temperatures of Lead-free soldering. Therefore it is not possible to transfer these electronic systems to go Lead-free.

Reliability issues

As part of the development of Lead-free technology, reliability testing has been carried out. With the use of pure Tin, a well-known effect comes back into play: Tin whisker formation. At the moment, it is possible to control whisker growth, but there is no clear model on how to accelerate this phenomenon. It can be proven, that under certain test conditions, such as high temperature and high humidity, there is no whiskers growth. But the knowledge on the phenomenon is not complete enough to guarantee that under real conditions – meaning after 15 years of operation in different climatic conditions – there is no risk of whisker growth.

The combination of different alloys with different component types is also a point of interest. In research programs it is not possible to have the same variety of populations on the board as in real world. Therefore it is not possible to obtain all the needed knowledge. It is not easy to replace the know-how collected in more than 50 years of real-life soldering experience with Lead-based electronic circuits.