

Part 1: Lead-free Implementation — Two Approaches

Part 1 of 4 outlines the two primary options in implementing lead-free electronics, while Part 2 provides the viable solder alloys for either of two approaches. Part 3 illustrates successful lead-free implementations and Part 4 summarizes critical production parameters.

In my annual new year forecast in SMT's January and March 2003 issues, I wrote: "Across the globe, environmentally friendly production, particularly lead-free electronics will be an essential action item during 2003. Much information related to Pb-free technology and implementation is available in the form of textbooks¹, prints and lecture series. Although Pb-free is a new material-process system, all fundamental principles and production-floor practices that have been developed for Pb-solders during the last 22 years are equally valid and applicable in implementing Pb-free solder manufacturing. In 2003, a select number of companies claim to be totally environmentally friendly Pb-free electronics producers."

During the first half of 2003, lead-free electronics manufacturing indeed became a reality, albeit with slow acceptance in North America. Globally, some manufacturers have reported completion of lead-free production, with some claiming success in partial implementation.

Within the lead-free system, comprising solder joint, printed circuit board (PCB) surface finish and component coating, the solder joint material (including BGA/CSP solder spheres) is relatively more demanding to replace. Concerning how to implement replacements for 63Sn/37Pb, the perceived elevated process (soldering) temperature was, and still is, the paramount issue. Concern about elevated process temperature is legitimate. However, the belief in an elevated process temperature as a prerequisite requirement is both true and false. How so? This depends on the alloy used.

There are two parallel approaches and, thus, methodologies. A drop-in approach means that the equipment, PCBs, components and primary processes do not need to be changed within the acceptable range of tolerances and variations. Bear in mind that minor process adjustments for 63Sn/37Pb have always been exercised to accommodate various assemblies and production lines. The modification approach involves one or more changes or modifications; for instance, increasing the soldering process temperature or changing PCB material. The main qualifiers and constraints in the context of having a quality solder paste and knowledgeable production personnel are the real-world SMT manufacturing environment, the diverse array of applications and assemblies, and established industry constraints, including acceptable flux chemistry, component availability, PCB cost and properties, etc. The most important measure, however, is production yield and long-term integrity and assembly reliability, including but beyond the solder joint per se.

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Under this premise, the practical demarcation between the two approaches is soldering temperature. Based on 22 years of SMT production, the best practices on the production floor dictate not only the production yield but also the long-term reliability. There is a "practical" peak temperature for reflow and wave soldering. Thus, to meet and exceed the manufacturing requirements in mass production, the drop-in approach requires a reflow peak temperature below 240°C, preferably below 235°C, and a wavesoldering temperature below 245°C. When the required reflow peak temperature or wave temperature rise higher, a modification approach is in order. Consequently, the required alloy's melting temperature is dictated by the process approach.

Even with today's machine capabilities and engineers' heightened knowledge in setting temperature profiles, the drop-in approach requires the alloy to melt at below 215°C. The 13-year steady, sustained study¹ of lead-free solder alloys has revealed that the ternary alloys cannot reach below 215°C, and only quaternary alloys can reach below 215°C. Both types of alloys are equally practical and commercially available. Certainly, this correlation is qualified under the best practices of SMT mass production and other practical constraints. The best practices and practicality exclude the incorporation of a high dosage of indium, bismuth and/or other low-melting elements for the reasons of cost or material metallurgy fundamentals; it also eschews the use of Zn-containing alloys because of flux chemistry. Are there some exceptions to this correlation? Yes. But they should be treated as exceptions, not the rule.

The two options are going with a higher-melting solder alloy under the modification approach using an elevated soldering temperature, or taking the drop-in approach using the right melting alloy. Switching the alloy between the two approaches should be diligently avoided. To implement lead-free successfully does not mandate an elevated process temperature, depending on which approach is elected.

Reference

1. Jennie S. Hwang, Environment Friendly Electronics — Lead Free Technology, Electrochemical Publications, Great Britain, 2001, 900 pages (ISBN: 0 901 150 401).



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