Electronic Equipment Supply Chain Lead-free (Pb-free) Transition Management

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References:

GEIA-HB-0005-1, Program Management/Systems Engineering Guidelines For Managing The Transition To Lead-Free Electronics, June 2006, Government Electronics and Information Technology Association

GEIA-STD-0005-1, Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder, June 2006, Government Electronics and Information Technology Association

GEIA-STD-0005-2, Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems, June 2006, Government Electronics and Information Technology Association (GEIA)

JEDEC Standard 201 (JESD201), Environmental Acceptance Requirements for Tin Whisker Susceptibility of Tin and Tin Alloy Surface Finishes, March 2006, JEDEC Solid State Technology Association

Discussion:

Background

The European Union (EU) Reduction of Hazardous Substances (RoHS) legislation enacted on 1 July 2006 prompted the rapid replacement of tin-lead (SnPb) finishes on electronic, electrical, and electromechanical (EEE) parts, often with pure tin, and introduces the possibility of commercial items incorporating Pb-free solder. Unfortunately for configuration control efforts, some manufacturers retain the same part numbers while changing part finishes (as well as changing mold compounds to eliminate brominated flame retardants). While the legislation has no direct bearing on US manufacturers, the global market implications mean US manufacturers will feel pressure to meet the EU requirements. Since US military programs rely on commercial items, both domestic and foreign sourced, the EU legislation requires that US military programs and equipment manufacturers develop and implement management approaches to mitigate the impact of these global supply chain changes in accordance with documents such as GEIA-STD-005-1, and GEIA-HB-0005-1.

The RoHS exemption for military equipment doesn't reduce potential impact on military programs and equipment producers due to the proliferation in the supply chain of Pb-free part finishes and possible introduction of Pb-free solder. The exemption does offer the opportunity to request SnPb finishes from suppliers, as well as NiPdAu (which is Pb-free, non-whiskering, and solderable) finishes. Recent part finish availability trends suggest that customer feedback to part manufacturers can succeed in greater adoption of NiPdAu finish, and longer retention on SnPb finishes.

Part Finish Effects

The Pb-free part finishes, including plated surfaces for soldering and solder balls, impact electronics reliability even if SnPb solder is retained. The primary issues are solder process material compatibility and tin whiskers.

The reflow temperature required for Pb-free solder balls is well above (~50°C) that for SnPb solder, so when using SnPb solder with these Pb-free balls will require Pb-free reflow profiles to properly reflow the balls. This higher temperature may cause a problem for some of the parts that may only survive typical SnPb solder profiles. The finish alloys may also form weak intermetallics or cause other effects that limit the life of the solder joint, so these interactions require assessment.

Tin whiskers can grow from pure tin finishes (>95% Sn with <3% Pb) and pose the risk of causing short circuits. GEIA-STD-0005-2 provides a framework for an effective tin whisker risk management plan tailorable to application sensitivity to system failure. For most military applications, control levels 2B and 2C provide appropriate requirements. Both require documentation of uses of pure tin, with level 2C requiring each application to be addressed and 2B covering classes of part families and application scenarios. Appropriate test requirements for tin finishes to establish whisker growth propensity, maximum whisker length and whisker density have not been developed to apply with confidence to military applications. JESD201 provides a baseline approach for commercial applications, but states “This methodology may not be sufficient for applications with special requirements, (i.e., military, aerospace, etc.). Additional requirements may be specified in the appropriate requirements (procurement) documentation.”

The requirements in JESD201 do not assess the synergies of various life cycle environments, such as temperature cycling, temperature, and humidity. An effective test approach for assessing the tin whisker risk of a pure tin finish will need to consider life cycle environments and hence sequences of environments, while JESD201 only imposes environments in parallel with some preconditioning to represent solder assembly processes.

Solder Joint Reliability

The Pb-free solders have significantly different material properties compared to eutectic SnPb solder, and there are also properties that are not sufficiently well characterized to allow effective solder joint reliability predictions. To evaluate solder joint reliability for long-term military applications requires some accelerated testing. The key parameters for developing an accelerated test include acceleration factors for dwell time, storage time, and temperature range, as well as failure distribution effects (acceleration factor for 1% cumulative failure may not be the same as for 50% or 63% cumulative failure often reported).

The most common family of Pb-free solders, tin-silver-copper (SnAgCu or SAC) alloys tend to have greater aging effects than SnPb, and have a higher modulus, which gives them greater strength, but less compliancy. More materials properties data is required for the Pb-free solder materials to develop appropriate accelerated test protocols to properly qualify these materials for military applications.

The GEIA Lead-free Electronics in Aerospace Project (LEAP) includes a working group developing an accelerated test protocol to address these issues. In addition, LEAP will release a technical handbook that outlines the broad range of technical issues with the Pb-free transition.

Lead-free (Pb-free) Transition Management for Military Applications

While the motivations for the global electronic supply chain transition to eliminate lead (Pb) from products, such as the recent European Union legislation and worldwide “green” manufacturing initiatives, do not apply specifically to military equipment, the suppliers of military electronics will need to establish management processes to assure that the transition does not impact military equipment reliability, availability, and maintainability. The unintended inclusion of Pb-free parts in military applications could result in significant reliability reduction due to tin whiskers and reduced solder joint life. Military program contractor and program offices should implement proactive plans to manage these effects on the supply chain and system design.