Lead-Free Implementation in the Global Market

Gene Vigilante
Sparton Corporation
Jackson, Michigan

Abstract
The Restriction of Hazardous Substances (RoHS) directive requires companies to change the way they design, manufacture, track, and bring new products into the market. In order to provide the necessary controlled processes for RoHS compliant electronic design and manufacturing, original equipment manufacturers (OEMs) and Electronic Manufacturing and design Service providers (EMS) must partner to develop product-based strategies. Tactics utilized are customized depending on the exact end market requirements.

Product Classifications
The affects of the RoHS directive resulted in three main product classifications — High-Reliability Exempt, Compliance Required, and Compliance Exempt — for establishing compliance strategies.

1. High-Reliability Exempt.

The high-reliability product is a classification of products that are RoHS exempt due to end market applications. Certain military, aerospace and the invasive medical device market are some examples. These products require elevated reliability standards for their operation, and are, therefore, exempt from environmental directives. Even though they are technically exempt from compliance, these products are significantly impacted by the rest of the industry's need to comply. Component manufacturers are switching to lead-free materials and processes, eventually discontinuing their lead-containing product lines. Since there are long-term reliability questions regarding lead-free parts and a lack of long-term data for the new replacement alloys, this product segment has several significant concerns.

There have been, and continues to be, significant Design-of-Experiments (DoE) and other studies by the global community with regard to long-term reliability issues including, but not limited to, tin whiskers. More long-term studies are required. Until these studies indicate a viable alternative, the use of Mil-Standard parts and tin-lead parts will continue with no end in sight. Commercial off-the-shelf (COTS), unfortunately, will not be synonymous with high-reliability within this product category.

Mitigation activities undertaken exclusively to control the risk of tin-whisker induced failures will inevitably increase cost, impose schedule penalties, and may affect system performances. The amount of mitigation employed must be traded against these costs at the system-level. Different systems exhibit different levels of tolerance for failure. This tolerance depends upon the criticality of the application, and the ability of the system to function in spite of the failure. OEM and EMS providers should have strategies and processes in place in order to mitigate risks of tin-whisker growth.

One such strategy has been developed by a consortium of OEMs called the Lead-Free Electronics for Aerospace Programs (LEAP). LEAP drafted an industry standard to control risks posed by tin whiskers. This standard, GEIA-STD-0005-2, entitled, "Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems" was released in June 2006. It is summarized below.

There are five mitigation levels developed to provide efficiency in contracts, design, procurement, and manufacturing.

- The highest level (called "Level-3") provides for maximum control. Pure tin finishes containing less than 3 percent by weight lead (Pb) are not permitted for use. All drawing notes and referenced specifications must be checked to verify that the prohibited finishes are not included. Control requires inspection verification of metal finishes on parts received.

- The next level below Level-3 is "Level-2C". Level-2C dictates that pure tin may be used only when there is no practical alternative and the risk of whisker-related failures is deemed it to be negligible.

- The third level ("Level-2B") provides for a moderate level of control. Pure tin finishes are only permitted when the risk of failure has been determined to be minimal and acceptable. The control allows for a generally wider use of standard components, if appropriate consideration has been given to the risks of system failure. Such systems typically permit repair and replacement of failed assemblies at the depot level as part of the logistics plan.

- The second level ("Level-2A") provides for minimal control. Pure tin finishes are restricted from use only in specific applications. This level permits the use of standard parts in all but a few limited applications. The intent is that some known or suspected problem applications can be restricted should the need arise with only minimal cost and schedule impact.

- The lowest risk level, "Level-1", provides for no control for pure tin finishes. All metal platings may be used without regard to issues of whiskering. This level is essentially a "best commercial practice," or COTS approach. Level-1 products are synonymous to the "compliance exempt" category described in section 3 below.

Additional design cycle considerations in determining and assessing risk should include:

- Spacing between adjacent interconnects.
- Plating finish on parts
- Physical barriers such as sleeving, conformal coat, potting, or other insulating barriers that can be used to protect against potential shorts.
- Pad and pin geometries where solder coverage may be incomplete or inadequate.
- Radio Frequency (RF) circuitries where protective coatings are undesirable due to performance degradation.

Once in the manufacturing cycle, a limited set of options are available to the OEM. Defensive strategies should be in place such as life-time part buys, purchasing from broker markets, purchasing from after-market foundries and lead re-plating or "lead-dipping". Adding sufficient control around change management, verification of incoming parts, and a closed-loop process for non-conforming materials is the last defensive gate before the product enters the market.

Products within this category are expected to experience mixed technology intrusions; that is, a mixture of tin-lead and lead-free parts within the same Bill-Of-Materials (BOM). Without sufficient controls in place, it is highly probable that a significant percentage of intrusions will make it to the board without the knowledge of the OEM. A research study conducted in the summer of 2005 by Avnet Electronics Marketing and Technology Forecasters Inc. (TFI), a market research and consultant services firm, indicated that 28% of component manufacturers have no plans to uniquely identify their lead-free components with a new part number. This should not present a significant problem if managed correctly during the product's design phase. The risks, however, are elevated with those products already in the production cycle because lead-free parts have been in the market pipeline for some time now.

OEMs and EMS providers should consider the product's life-cycle and underlying costs (both non-recurring and recurring) before determining which risk-mitigating tactics should be used. Accelerated obsolescence of tin-lead parts by manufacturers not wishing to support both tin-lead and lead-free production lines is anticipated. According to TFI / Avnet, the 2005 study indicated that only 36% of suppliers have plans in place for handling non-compliant inventory, and 31% have no plans to offer tin-lead components. It is evident that component life-cycle analysis and obsolescence management should become part of the product's overall part mitigation and issue containment plan.

2. Compliance Required

This category includes products that must be compliant, as outlined by the EU directives. Compliance is clearly a business issue for these OEMs. Legislation will determine compliance requirements; but it will be the market that will determine alloys used, component availability, and the manufacturing services offered.

As in the high-reliability category, mixed technology intrusions will be of significant concern, especially with the products that are currently in the production cycle. OEMs and EMS providers must have strategies and processes in place in order to mitigate the risk of mixed technology intrusions.

For new products or product re-designs, designers should address compliance restrictions early in the design cycle. Engineers need to be aware of the current regulations requiring complete compliance records and the ramifications of using substitutes to replace restricted substances. Compliance records should include restricted substance disclosures, Certificates of Compliance (C of C), supplier audit reports, component risk evaluation procedures to demonstrate “due diligence”. Due diligence under the directive requires that OEMs take “reasonable steps” to restrict hazardous substances in their products. Many of the OEMs surveyed for the 2006 TFI study are employing multiple “reasonable steps” to restrict substances. Nearly all are collecting and recording supply-chain materials declarations. About half are analyzing materials themselves using chemical testing, and about half are using automated data systems that document information for audits.

Records should include data for moisture sensitivity levels (MSL), component plating finishes, maximum reflow temperatures, thermal balance of boards, and compatible printed-circuit-board (PCB) platings.

Early involvement with the EMS companies during the design cycle is the recipe for success. Component costs are not expected to be a significant cost driver. The cost drivers, however, lie in the higher temperature manufacturing processes, legislative requirement overhead and the infrastructure required to track it all.

An April 2006 poll, conducted by Arena Solutions, indicated that 65 percent of respondents would not be able to confidently report compliance based on complete and accurate product compliance records. The RoHS Readiness Survey focused on 16 key capabilities surrounding tracking, documenting and reporting of RoHS compliance.

The survey found that a majority of respondents had implemented a RoHS transition plan, 69 percent indicated that they did not have a centralized compliance management solution in place that was accessible to employees and suppliers. Having a reliable compliance management system in place is critical to the long-term success of the product in the marketplace. The survey found that 63 percent of respondents recognize that their current solution to track compliance will not scale for multiple regulations.

Implementing a proactive design, manufacturing and information management strategy will facilitate migration to RoHS / WEEE compliance.

3. Compliance Exempt

These are products that do not need to be RoHS compliant due to special wavers, exemptions or to their limited product life. There is a high probability that these OEMs will not be concerned with mixed technology intrusions in their products since both tin-lead and lead-free components are compatible with the current tin-lead manufacturing processes. However, EMS providers must still bear the added inventory control and logistical costs due to the global compliance challenge. The biggest challenge within this category will be part obsolescence.

A Product-Based Strategy

EMS companies are expected to support the dual manufacturing environments. Requirements dictate that these companies provide services to all three product categories and have the capability and flexibility to run both tin-lead and lead-free manufacturing processes. Service providers must be able to distinguish between compliant and non-compliant parts; adjust manufacturing processes on the fly, and maintain the required information and control processes necessary for the required operation. A multi-phase plan was adopted by Sparton Corporation to address all three categories.

BOM analysis is the first and the most essential phase. The goal of this phase is to determine the product’s current state of compliancy. The outputs will identify component non-compliances so as to implement near-term tactics and to baseline discussions for optimal long-term program strategies. Whether a new design or an existing product, a BOM analysis should be done periodically irrespective of the product’s category or exemption status. There are two sub-levels of analysis; a lower-cost “preliminary” analysis and the “full-disclosure” analysis.

The “full-disclosure” RoHS compliancy analysis is available to customers that require RoHS compliant product conversions. The full-disclosure analysis satisfies the due diligence and disclosure requirements by providing full component material content documentation or Certificate of Conformance (C-of-C). Additionally, the full-disclosure analysis includes vital information necessary for the product to run on any lead-free manufacturing line at any contract manufacturer. Analysis should ascertain the compliancy status of parts… whether the part contains lead, is lead-free but not RoHS compliant, or is fully RoHS compliant. RoHS, life-cycle, and alternate search analyses are performed using several third-party BOM scrubbing services. Component engineering services are used to reconcile anomalies and discrepancies among the third party reports. Data is archived in a centralized database and made available to Sparton associates and customers.

In order to comply with RoHS disclosure requirements and be compatible with the lead-free manufacturing process, the parts database will contain additional part attributes such as plating finishes used on second-level interconnects (i.e. leads, balls, connector pins), Moisture Sensitivity Levels (MSLs), hazardous substance concentrations / manufacturer's C-of-C, compliance date, package date code, and process limits (i.e. maximum package temperatures).

The "preliminary" analysis is available to customers that are considering product design, redesigns, estimating compliancy conversion costs, assessing risk of exempt high-reliability products, or require market information in order to determine the optimal business strategy based on the current state of technology. At a minimum, the preliminary analysis should ascertain the compliancy status of BOM, including life-cycle screening information, and alternate part availability for obsolete parts or for non-conforming material.

The first-article or prototype build is the second phase and is recommended for all compliancy-required products but is optional for the exempt high-reliability category.

Entry into this phase assumes that the current BOM content is considered to be in compliance with the product's classification and customer's requirements, or can easily be converted to their conforming part alternates with minimal effort (i.e. alternates are form, fit, and functionally equivalent [FFF] to the original part). Completion timeline for this phase depends on the unresolved issues identified during the first phase, product complexity, and process challenges.

Should this phase indicate that a significant effort is required (i.e. non-compliant parts are encountered and/or part obsolescence is present), the customer may hold or terminate first-article or prototype efforts in order to mitigate issues or reevaluate product strategies.

Supplier qualifications are performed, board laminates and pad surface finishes are selected, and solder paste & alloys are determined.

Use of certain lead-free alloys may result in higher temperature profiles during board assembly and rework. Therefore, a part-process compatibility and board thermal balance analysis are performed to determine which parts can tolerate elevated temperatures from those that cannot. The cost impacts due to parts requiring manual assembly should be considered during the design cycle.

A product first article or a prototype build will conclude this phase. This phase should be implemented in accordance with the product development and validation requirements. Due to the material and availability uncertainties, it is not possible to execute this phase until the initial BOM analysis phase has been successfully completed.

Summary

This is clearly an issue facing both OEMs and EMS providers in today's global market. The RoHS directive requires companies to drastically change the process in which they design, manufacture, and bring new products to the market. Only through detailed planning and effective implementation can OEMs successfully manage their compliant design and manufacturing strategy. The key for OEMs and EMS providers is adding sufficient control around change management, verification of incoming parts, and a closed-loop process for non-conforming materials.