How do you create a RoHS Compliancy-Lead-free Roadmap?

When a company begins the transition to lead-free it impacts the whole organization. The cost of transition will vary and depends on the number of assembly processes present, age of the equipment and the complexity of the assemblies. It requires solid management commitment.

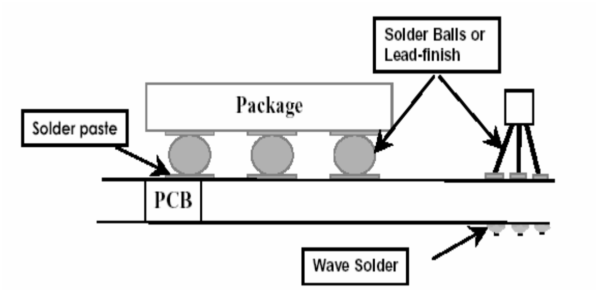
Transitioning to lead-free in all processes at your facility can be enhanced with the assistance of your suppliers. From equipment manufacturers to component and board suppliers, a vast amount of knowledge has been gained in the last 6 years. Many suppliers have been researching and developing lead-free compatible products to enable reliable lead-free assembly without loss to production outputs. This know-how, when shared with the customer can save a company thousands of dollars in engineering time and avoids false starts and reliability issues.

Great progress has been had in recent years with lead-free assembly, and lead-free products are now available around the world. Equipment suppliers have made adjustments to their equipment accommodate lead-free soldering. Many industry equipment leaders have been instrumental in establishing the process knowledge to enable lead-free soldering. Inspection methods have been refined to deal with the lead-free solder joint integrity. Component and board issues have been addressed in most cases. Rework techniques have been re-defined and equipment is available.

Transitioning to lead-free soldering and RoHS compliancy is a lot more than choosing a lead-free solder.

There will be equipment compatibility issues to investigate, component and board procurement and compatibility problems to address. There will be lead-free process validation studies, lead-free product implementation plans to execute and training for line supervisors and operators to be done. All this takes a company's commitment, resources and a solid understanding of the potential pitfalls.

The figure to the right indicates where the assembly must be lead-free. The solder paste and wave solder alloy must be lead-free but also the SMD terminations, through-hole leads and board finishes must not exceed 0.1% lead. The RoHS directive was recently clarified to require no more than 0.1% lead on these surfaces, each should be considered in the selection process.



The first thing a company must do is to create a **RoHS Compliancy Team**, comprising of manufacturing engineers, purchasing, inventory, training and quality personnel. In many cases reliability test engineers are also involved, since the components and boards will change as will the solder; it may be necessary to verify the reliability of the lead-free, RoHS compliant assembly.

Procurement and Inventory Control

The purchasing personnel will have to work closely with board and component suppliers to insure lead-free compatible parts are available. Lead-free boards will also have to be sourced. In both these cases, they will have to be not only lead-free but also compliant to other requirements of the RoHS directive that is for example cadmium-free and halogen-free. It is recommended that all purchasing personnel familiarize themselves with these new requirements, since they involve more than the elimination of lead, cadmium and halogens.

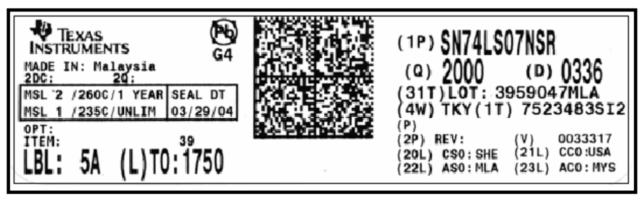
The lead-free SMD components will have to be in many cases compliant to the J-STD-020 for moisture sensitive levels for lead-free assembly. This standard will dictate the thermal profiles the components can withstand without damage. Many lead-free components are also following the marking guidelines set forth by the JESD97, as to the finish that will be available on the leads and also the type of interconnect used in BGA's.

The following is a summary of the requirements for RoHS compliancy for components.

- **Lead-free finishes**
- **Thermal compatibility with the assembly process**
- **Plastic molding compounds thermal compatibility**
- **Halogen-free plastics**
- **Moisture sensitivity level changes**
- **Shelf-life and logistical control**

To simplify the process, an Excel spreadsheet can be created by procurement and sent to each supplier. The supplier can indicate compliance to the RoHS, J-STD-020, and JESD97 for each component. The components may have new part numbers, and work is ongoing to standardize the markings used to identify green components and boards.

On the right a typical component label is shown. This label indicates the alloy code G4 and the MSL rating. It is lead-free and the lead-free symbol helps to identify this. Many suppliers are now using similar identification as per the JESD97.



The process of searching out lead-free, RoHS components will be a demanding exercise. Boards will be easier to obtain. Here various lead-free finishes are available. They should be selected for ease of soldering, prolonged storage, and reliability of the final assembly.

In reference to circuit cards the following summarizes the requirements for RoHS compliancy and lead-free assembly:

- **Lead-free board finishes, OSP, immersion Tin, Silver Immersion, Gold/ Nickel, etc**
- **Thermal compatibility with lead-free process, Tg change possible**
- **Halogen-free laminate**
- **Halogen-free solder mask**

The component selection process usually takes a company the longest time in the transition. It can take as little as 3 months to more than a year. For this reason a company may choose to build one product at a time in a lead-free format.

Components and boards that aren't for lead-free assembly will have to be depleted and then replaced with RoHS compliant items. Careful control of inventories will be necessary to minimize waste and added costs.

Manufacturing and Engineering

Process engineers will have to determine the lead-free alloy and flux systems to be used. Working with a solder supplier who has solid lead-free experience will save considerable time and money. Choosing the right alloy for the assembly and the right lead-free flux system will insure reliability and also will help maintain production yields. The flux should be selected carefully as to manage solderability. Flux systems for lead-free and wave assembly will be more thermally stable than flux systems used with 63/37. Selecting soldering materials carefully can prevent many costly defects and increase reliability.

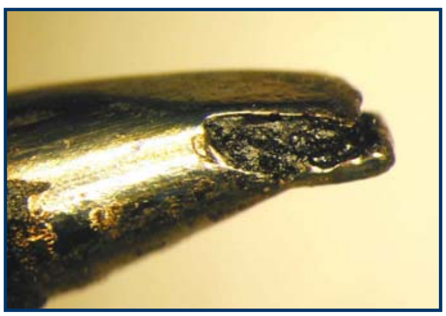
For example below are typical characteristics to be sought during the solder paste selection process:

- **Flux system able to solder a variety of surface finishes**
- **Good cold and hot slump properties**
- **Low bridging and solder ball potential**
- **Low voiding potential**
- **Low decomposition; low condensate**
- **Clear residues, if no-clean type**
- **Pin-testability of no-clean residues**
- **Cleanability in water if required**

The equipment will have to be lead-free compatible. For example the wave solder machine will require leach resistant solder pots, impeller, and ducting to avoid iron erosion with the higher tin containing lead-free solders such as tin-silver-copper and tin-copper alloys.

The reflow oven will have to be able to give higher peak temperatures in the range of 230-245°C, but also be able to maintain production outputs at these thermal profiles.

Soldering irons for example will require lead-free tips to avoid reduced tip life due to tin erosion.



The picture on the left shows a tip destroyed by tin erosion when using lead-free solders. In this case the tip life was only three weeks. Traditionally the user had been used to a tip life averaging 3 months with leaded 63/37.

To avoid the escalation of tips used per year, LF tips should be used. These tips have additives in the iron to reduce leaching. Avoiding using higher tip temperatures will also reduce the erosion and prolong tip life.

Rework stations for BGA components will require narrower temperature control and the ability to sustain smaller Delta T's; they will have to be tested to determine if they are lead-free compatible. Bottom heating may be required for BGA rework since the thermal profile will be narrower. To reflow BGA's if Tin-Silver-Copper balls are present will require a minimum temperature of 217°C and a maximum of 245°C or lower. The Delta T is lower than with a 63/37 process. To avoid component damage often a Delta T of 5°C is prescribed by component manufacturers across the lid of the component.

From an ease of implementation, the easiest to the most difficult lead-free process to transition to is as follows:

- **Hand-soldering, may require technique modifications**
- **SMT Reflow, may require reduction in conveyor speed**
- **Wave Soldering, may require solder pot change**
- **Rework, may require equipment changes**

Lead-free may require the implementation of other process verification methods such as X-Ray, to examine lead-free joints for voids. This is especially true with lead-free BGA assembly where voids or insufficient reflow and poor wetting can occur. However, optical inspection systems are best suited to examine joints for wetting performance and detecting hairline fractures.

Documentation and Training

Lead-free solders offer different wetting behaviors and also less reflective cosmetics. Training will be required so operators will be in a position to recognize good lead-free solder joints. Lead-free solder joints tend to have larger contact angles, reduced spread and grainy surfaces. At this time there is no document or unique standard which can be used as a lead-free guide, the IPC will be issuing and addendum to the J-STD-610C in the first quarter of 2005. However the IPC-610-C still applies when soldering with lead-free solders.

Solder Paste		**OSP PCB**			**NiAu PCB**		
		SnPb	Sn	SnCu	SnPb	Sn	SnCu
SnPb	Class 1	Pass	Pass	-	Pass	Pass	Pass
	Class 2	Pass	Pass	-	Pass	Pass	Pass
	Class 3	Pass	Pass	-	Pass	Pass	Pass
SnAgCu	Class 1	Pass	Pass	Pass	Pass	Pass	Pass
	Class 2	Pass	Pass	Pass	Pass	Pass	Pass
	Class 3	Pass	Pass	Pass	Pass	Pass	Pass
SnAg	Class 1	Pass	Pass	Pass	Pass	Pass	Pass
	Class 2	Pass	Pass	Pass	Pass	Pass	Pass
	Class 3	Pass	Pass	Pass	Pass	Pass	Pass
SnAgCuBi	Class 1	Pass	Pass	Pass	Pass	Pass	Pass
	Class 2	Pass	Pass	Pass	Pass	Pass	Pass
	Class 3	Pass	Pass	Pass	Pass	Pass	Pass
SnAgInBi	Class 1	Pass	Pass	-	Pass	Pass	Pass
	Class 2	Pass	Pass	-	Pass	Pass	Pass
	Class 3	Pass	Fail	-	Pass	Pass	Pass
SnBiZn	Class 1	Pass	Fail	Pass	Pass	Fail	Fail
	Class 2	Pass	Fail	Pass	Pass	Fail	Fail
	Class 3	Fail	Fail	Fail	Pass	Fail	Fail

IPC-610-C Gintic Consortium Study using different paste alloys

The above chart shows inspection performed during the Gintic Consortium Study in Asia. As can be seen most SMT solder joints met the IPC-STD-610-C criteria. The exceptions were the SnAgInBi and SnBiZn joints, but the most popular lead-free solder choice is by far Sn-Ag-Cu. This study involved soldering SnPb, Sn, and SnCu terminations on different boards pads such as copper and gold/nickel and then observing the joint geometries for compliance.

Even if guides were available, it is important to train all personnel on the techniques to create good solder joints. For example, in hand-soldering operators will notice immediately that the flow of solder will seem reduced and the first item of the day will be to increase soldering iron temperature. The correct way will be to set the irons at 700-800 °F maximum, and use a flux designed for lead-free and possibly then only increasing the contact time with the iron.

Training of all personnel from purchasing to manufacturing and final assembly will prevent reliability issues and cross contamination problems especially where dual systems, leaded and unleaded assembly is being performed.

It is also mandatory to review ISO documentation for compliance, updating or adding documentation to support the lead-free initiative. This is usually done after lead-free assembly has undergone process development, validation and reliability assessment.

If a product is to be reworked in the future it will require adequate identification so proper lead-free methods are used. Also once a company achieves the ability to assembly with lead-free solders and is RoHS compliant this can be a business advantage and should merit some sales and marketing effort. This is particular true with contract assemblers since OEM's will be seeking assemblers that can offer them products which can be sold around the world without the limitations of the WEEE (Waste From Electrical and Electronic Equipment) or RoHS directives.

Summary of Actions - Roadmap to RoHS-Lead-free Compliance

- **Management buy-in and commitment**
- **RoHS-Lead-free Team**
- **Component and Board Supplier RoHS Compliance Reports**
- **Equipment change requirements**
- **Process development**
- **Process validation**
- **Reliability testing**
- **Training**
- **Document control and ISO changes**
- **Field rework practices**
- **Sales and Marketing**

The above is only a summary of some of the requirements needed to create a solid RoHS/Lead-free roadmap. The transition to lead-free is being achieved reliably around the world, but it takes proper planning, dedication and time. A successful transition can take 6 months to more than a year. The time to start is now, if a company is to meet the July 1, 2006 deadline.

About the author:

Peter Biocca is Senior Market Development Engineer with Kester in DesPlaines, Illinois. He is a chemist with 24 years experience in soldering technologies. He has presented around the world in matters relating to process optimization and assembly. He has been working with lead-free for over 8 years.

He has been involved in numerous consortia within this time and has assisted many companies implement lead-free successfully. He is an active member of IPC, SMTA, and ASM. He is the author of many technical papers delivered globally. He is also a Certified SMT Process Engineer.

For more information on how to create a RoHS-Lead-free Roadmap for your company, please contact Peter Biocca at 972.390.1197 or pbiocca@kester.com