

SMT Lead-Free Packages

Application Note

Products Affected: M211111, M21121

Introduction

The objective of this application note is to provide the basic SMT design and process requirements necessary to ensure high assembly yield and product reliability for lead-free packages. Mindspeed has taken a proactive role and worked with our suppliers and customers to develop and qualify material sets and processes for lead-free applications. For most of our lead frame base packages, pure matte Sn plating was selected, and for the BGA packages Sn-3-4%Ag-0.5%Cu solder ball was used. These materials are industry's preferred materials and are widely available. The lead frame base packages with matte Sn plating are backward compatible with eutectic Sn/Pb SMT process; however the lead-free BGA packages with SnAgCu balls are not recommended to be used with eutectic Sn/Pb SMT process. Mindspeed lead-free packages comply with the most recent JEDEC J-STD-020 specification for peak reflow temperature requirements (260 °C for smaller size packages, 250 °C for medium size packages and 245 °C for larger size packages. Package size is defined in the [Table 1](#)). Standard package reliability tests include temperature cycles, biased HAST, and high temperature storage.

The SMT process for lead-free packages is slightly different from the eutectic Sn/Pb solder process due to the material set difference. The lead-free material sets require higher reflow temperatures during SMT process. The important factors that affect the SMT process and product reliability are discussed in this application note.

Printed Circuit Board

The general PCB design rules for lead-free solder and Sn/Pb solder application are the same. Only the board surface finish and the board material have to be considered for lead-free application due to the higher reflow temperature and lead-free solder compatibility.

- a. **PCB Surface Finishes.** The most common surface finishes that are compatible with lead-free SMT process are:

- Organic Solderability Preservatives (OSP)
- Electroless Ni/Immersion Au (ENIG)
- Immersion Ag
- Immersion Au

Selection of a suitable finish will depend on end user's requirements of board design, assembly process, handling/storage, and cost.

- b. **PCB Materials.** Due to the higher reflow temperature requirement of the lead-free material set, the board material with higher Tg (> 170 °C) is recommended.

SMT Printing Process

- a. **Solder Paste.** SnAgCu eutectic solder with melting temperature of 217 °C is most commonly used for lead-free solder reflow application. This alloy is widely accepted in the semiconductor industry due to its low cost, relatively low melting temperature, and good thermal fatigue resistance.
- b. **Stencil Design.** The recommended stencil is laser-cut, stainless-steel type with thickness of 5 to 7 mils and approximately a 1:1 ratio of stencil opening to pad dimension. To improve paste release, a positive taper with bottom opening 1 mil larger than the top can be utilized.
- c. **Printing Process.** Printing process requires no significant changes compare to Sn/Pb solder. Any guidelines recommended by the paste manufacturers to accommodate paste specific characteristics should be followed. Post-print inspection and paste volume measurement is very critical to ensure good print quality and uniform paste deposition.
- d. **Placement.** With the self-aligning characteristic of the BGA packages during reflow, the placement accuracy is not very critical. A placement offset of 30% of the pad diameter or as long as the solder balls can touch solder paste, they will self-align after reflow.

SMT Reflow Process

The optimization of the reflow process is the most critical factor to be considered for the lead-free soldering. The development of an optimal profile should take into account the paste characteristics, the size of the board, the density of the components, the mix of the larger and smaller components, and the peak temperature requirements of the components. An optimized reflow process is the key to ensure successful lead-free assembly and achieve high yield and long term solder joint reliability.

- a. **Temperature Profiling.** Temperature profiling should be performed for all new board designs by attaching thermocouples at the BGA solder joints, on the top surface of the larger components as well as at multiple locations of the boards. This is to ensure that all components are heated to temperature above the minimum reflow temperatures and the smaller components do not exceed maximum temperature limit. The targeted BGA solder joint temperature for the SnAgCu solder should be ~ 235 °C. For larger or sophisticated boards with a large mix of components, it is also important to minimize the temperature difference across the board to be less than 10 °C to minimize board warpage.
- b. **Reflow Profile Guidelines.** The solder reflow profile should follow the paste manufacturer's recommendation and the general JEDEC/IPC standard J-STD-20 guidelines. [Figure 1](#) shows the range of temperature profiles of The J-STD-20 specification. The profile parameters and component peak temperature guidelines are listed in [Table 1](#) and [Table 2](#). Note all specified temperatures in [Table 1](#) and [2](#) refer to the temperatures measured on the top surface of the package.

Figure 1. JEDEC Recommended Lead-Free Reflow Profile

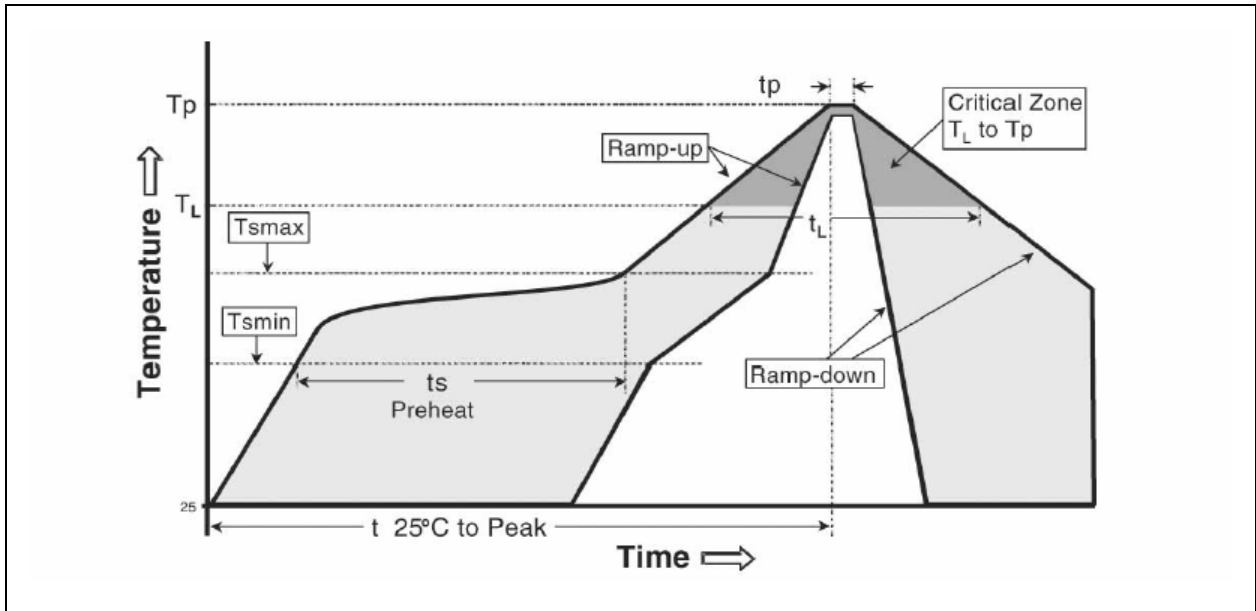


Table 1. Lead-Free Reflow Profile Parameters

Profile Parameter	Lead-Free Assembly, Convection, IR/Convection
Ramp-up rate (Tsmmax to Tp)	3 °C/second max.
Preheat temperature (Tsmmin to Tsmmax)	150 °C to 200 °C
Preheat time (ts)	60 – 180 seconds
Time above TL, 217 °C (tL)	60 – 150 seconds
Peak temperature (Tp)	Per Table 2 below
Time within 5 °C of peak temperature (tp)	20 - 40 seconds
Ramp-down rate	6 °C/second max.
Time 25 °C to peak temperature	8 minutes max.

Table 2. Peak Reflow Temperature of Mindspeed Lead-Free Package

Package Thickness (exclude external terminals/leads, BGA balls and not integrated heat sinks)	Volume mm ³ < 350	Volume mm ³ 350 - 2000	Volume mm ³ > 2000
< 1.6 mm	260 °C	260 °C	260 °C
1.6 mm – 2.5 mm	260 °C	250 °C	245 °C
> 2.5 mm	250 °C	245 °C	245 °C

It is very important to control the peak reflow temperature below the maximum temperatures specified in Table 2 to prevent thermal damage to the package. All Mindspeed lead-free packages are qualified for up to three times reflow at peak temperatures in accordance with Table 2.

- c. **Reflow Oven.** It is strongly recommended that a reflow oven equipped with more heating zones and Nitrogen atmosphere be used for lead-free assembly. Oven with more heating zones offers higher flexibility to optimize the reflow profile for complex and/or larger boards. Nitrogen atmosphere has shown to improve

the wettability and reduce temperature gradient across the board. It can also enhance the appearance of the solder joints by reducing the effects of oxidation.

Post Reflow Visual Inspection

Lead-free solder joints are not as shiny as the Sn/Pb solder joints. In addition, solder fillet profile is generally not as great as with the Sn/Pb solder joints. The inspectors should be trained to distinguish lead-free solder joints from Sn/Pb solder joints.

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