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Solder Joint Temperature and Package Peak Temperature

Determining Thermal Limits during Soldering

Contents

1 Processability of Integrated Circuits

JEDEC/IPC J-STD-020 (http://www.jedec.org) is a Joint Industry Standard of Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices. This document demonstrates how to determine the package temperature and thermal mass dependent moisture sensitivity level (MSL) of products to ensure reliable processing of moisture sensitive surface mount components. Comply with these recommendations to maintain package integrity of components during any heat exposure of board soldering and de-soldering.

The relevant temperature is measured at the top of the parts and is defined as package peak temperature (PPT). This package temperature is often also named peak reflow temperature (PRT) which — because of reflow in the technical term — can be misleading to take the temperature in the solder joint where the material reflow happens. It is important to note that the PPT is the reference temperature for the parts' MSL. The PPT must not be confused with the solder joint reflow temperature, the MSL/PPT Classification Profile is not for component board soldering in production lines.

MSL and PPT belong together and are product characteristics reflecting the robustness of semiconductor components for board soldering. They tell how long the parts are allowed to be exposed to a controlled environment before it is necessary to dry-bake them again before any first or subsequent soldering step. Absorption of water has to be kept at a tolerable level so that no popcorn effects compromise parts' reliable performance later on. Table 1 is a partial list of the J-STD-020C MSL guidelines of processing rules for correct storage and handling prior to soldering. The standard is also important for double-sided reflow such as for top and bottom side board assemblies where it is mandatory to prevent excess moisture take-up of the plastic components during storage before they will see a second exposure to soldering heat. This best practice advice is also applicable for any re-work, service and repair soldering step.

Table 1. MSL per J-STD-020C

Moisture SensitivityLevel (MSL)	Dry-Packing Required	Floor Life	
		Time	Conditions
1	No	unlimited	</=30°C/85%RH
2	Yes	1 year	</=30°C/60%RH
2a	Yes	4 weeks	</=30°C/60%RH
3	Yes	168 hours	</=30°C/60%RH
4	Yes	72 hours	</=30°C/60%RH
5	Yes	48 hours	</=30°C/60%RH
5a	Yes	24 hours	</=30°C/60%RH
6	Yes	time on label	</=30°C/60%RH

As indicated, the technical justification for the series of the J-STD-020 standard and its importance for the industry is based on the inherent behavior of components where plastics are used for encapsulation, glue, seal, or underfill, all of which absorb more or less water at slower or faster speed. As existing voids and gaps fill with water, the material properties such as thermal coefficient of expansion change and the adhesion at interfaces weakens.

There is a conflict of interest between good solder joint formation of hot and fast soldering versus maintenance of good package integrity by keeping the package temperature low and also by using slow temperature gradients. This becomes a problem with a solder joint temperature (SJT) range of 235–245°C for Pb-free SnAgCu solders that have a liquidus between 217– 227°C. That is higher than the usual SJTs of nearly eutectic SnPb solders with 205–220°C and liquidus between 179–183°C. The different temperature scenarios for conventional SnPb and Pb-free SnAgCu board soldering are outlined in Table 2.

Table 2. Typical Minimum SJT and Maximum PPT for SnPb and SnAgCu-Based Board Soldering, Accounting for Package Size

Solder Paste Liquidus	SnPb-based 179–183°C		SnAgCu-based 217–227°C	
	Max PPT	Min SJT	Max PPT	Min SJT
Large, thick packages	225°C	205–220°C	245°C	235–245°C
Small, thin packages	240°C	205–220°C	250–260°C	235–245°C

Board assemblies use a mix of package types of different materials and dimensions that results in a spread of thermal mass and heat conduction on the boards. Uneven heat distribution, plus oven and process tolerances, are reflected by a temperature difference (delta-T) on the various boards ranging in size, component dimensions, materials, arrangement, and density. Detailed investigations were performed to characterize the thermal conditions at components during reflow soldering where the process window is narrowed for Pb-free. Figure 1 shows the relevant temperatures and where to measure them for reliable board production.

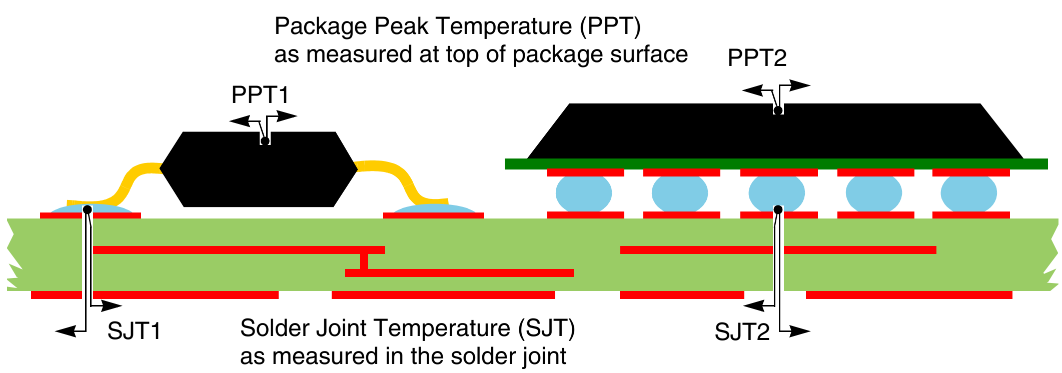

Figure 1. SJT and PPT Must be Determined for Critical Components on the Boards

In infrared or convection processes the temperature can vary greatly across the PC board, depending on the furnace type and on the size and mass of components, and their location on the board. Profiles must be carefully tested to determine the coolest solder joint and the hottest package on the board. Oven settings have to ensure the minimum SJT is reached long enough for good solder joint formation including self-registration of the component in the solder bed. At the same time, the specified PPT of any component on the board must not be exceeded. Thermocouples must be carefully attached with very small amounts of thermally conductive grease or epoxy to the package top for PPT, directly to the solder joint interface between the package leads and board for the SJT measurement.

Table 3 and Table 4 outline the changed thermal stress scenario on package bodies during the conventional SnPb process compared to Pb-free soldering. The shown temperature classes based upon J-STD-020C and depend on package volumes and thicknesses giving guidelines for product classification which, however, must be verified in the real board production environment to prevent excess package temperatures can affect parts’ mechanical integrity.

Table 3. SnPb Eutectic Process — PPT

Package thickness	Volume mm^3 < 350	Volume mm^3 ≥ 350
<2.5 mm	240 +0/–5°C	225 +0/5°C
≥ 2.5 mm	225 +0/–5°C	225 +0/5°C

Table 4. Pb-Free Process – PPT

Package thickness	Volume mm^3 < 350	Volume mm^3 350 – 2000	Volume mm^3 > 2000
<1.6mm	260+0°C[1]	260+0°C[1]	260+0°C[1]
1.6mm – 2.5mm	260+0°C[1]	250+0°C[1]	245+0°C[1]
≥2.5mm	250+0°C[1]	245+0°C[1]	245+0°C[1]

[1] Tolerance: The device manufacturer/supplier shall assure process compatibility up to and including the stated classification temperature (this means peak reflow temperature +0°C. For example, °C+0°C) at the rated MSL level.

MSL/PPT is a product characteristic. Freescale Semiconductor determines the MSL of the components using the PPT Profile (Figure 2) as measured with a thermo couple at the package top surface. This profile builds on J-STD-020C and reflects customers' requirements and their production processes, which were evaluated for standardization.

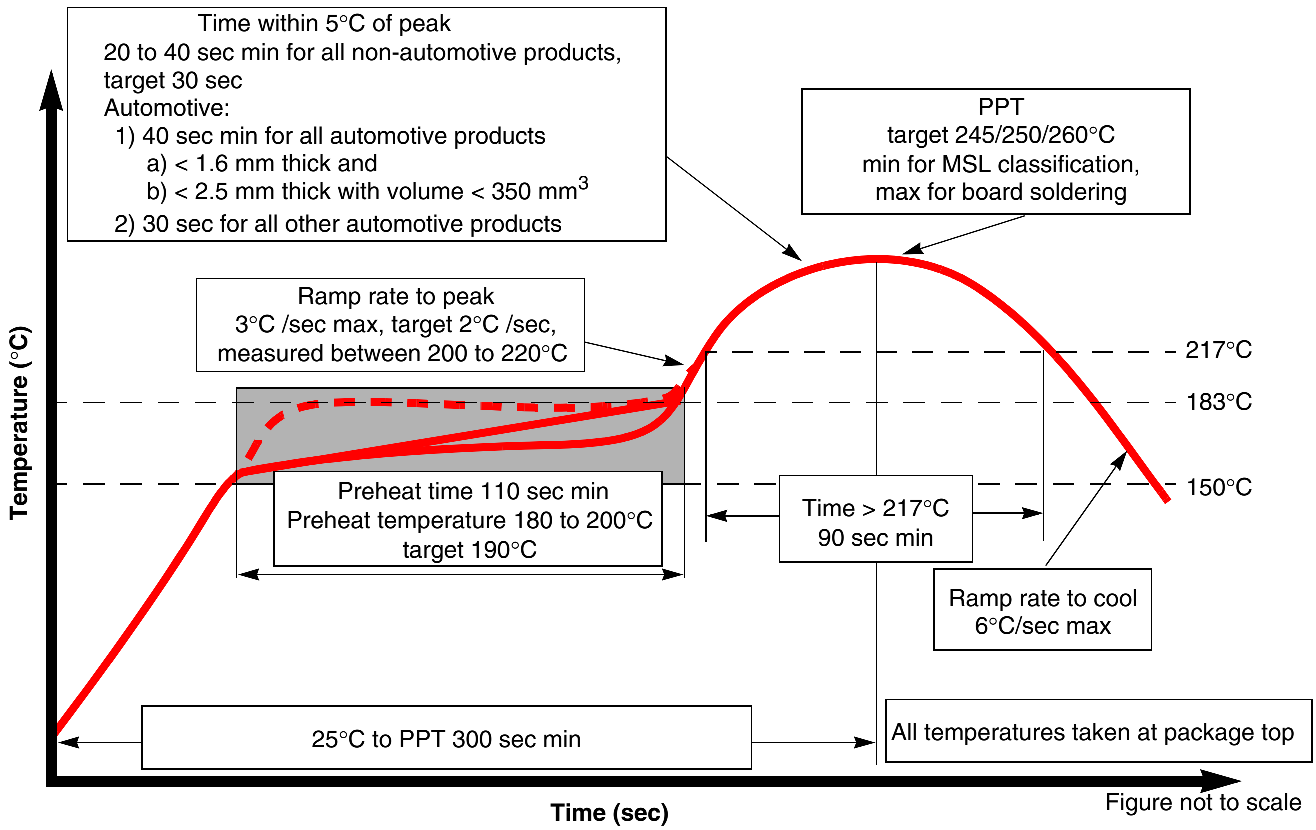

Figure 2. PPT Profile for Determination of Components' MSL and the Parts' Processability per J-STD-020, Including Customer Board Soldering Requirements

2 Mixed Assemblies – Board Soldering of Pb-free Terminated and Conventional Components

Not all components with the required solder finish will be available during the migration from conventional SnPb to the coming Pb-free board soldering. Conventional SnPb parts will be on Pb-free boards and already converted Pb-free components will land on printed circuit boards, which also run through traditional SnPb soldering processes. There is only a conditional okay to be given for forward compatibility, such as SnPb into Pb-free, but not backward compatibility, such as Pb-free into SnPb. Freescale offers a portfolio of environmentally preferred products (EPP) which are RoHS compliant and also provide the necessary MSL/PPT for Pb-free board assemblies.

In the case of mixed assembly, the parts' MSL/PPT must be adequate for the higher thermal stress and exposure during Pb-free soldering if soldering conventional SnPb components under Pb-free conditions. Dry-baking prior to soldering might be necessary. SnPb solders melt and give good solder joints without problems in both air and nitrogen atmospheres solder ovens and at normal Pb-free process temperatures.

Freescale's EPP Pb-free leadframe parts can be put on boards with SnPb solders and no changes have to be made to the SnPb process with typical SJTs between 205 and 220°C. The SnPb solder finish or paste on the board rule the solder system and are not influenced by the minute amount of Pb-free solder on the leads. Good solder joints form, the component reliability is unaffected as its MSL/PPT is superior to the SnPb process conditions and commonly established MSL/PPT rules were completed during the board soldering and related handling.

The situation is different if soldering EPP ball grid arrays (BGA) with their SnAgCu solderballs on to boards with SnPb solder paste. Take care for a complete melt and mix of both solder reservoirs of paste bumps and balls. Now the large volume of the solder balls determines the necessary temperatures and soldering kinetics. The paste volume disappears into the ball and both form the final joint. The process is well set when the dual collapse of the BGA towards the board can be observed. The BGA has to sink into the paste and further moves towards the board when the solder balls melt. Then enough time has to be given that the parts swim and center. The molten solders form a homogenous connection. Experience shows that SJTs of greater than 225°C yield reliable solder joints between SnPb pastes and SnAgCu balls. That is higher than the upper end of normally established 205–220°C in the joints of SnPb soldering. Figure 3 shows the conditional forward and backward compatibility and crucial areas for special attention.

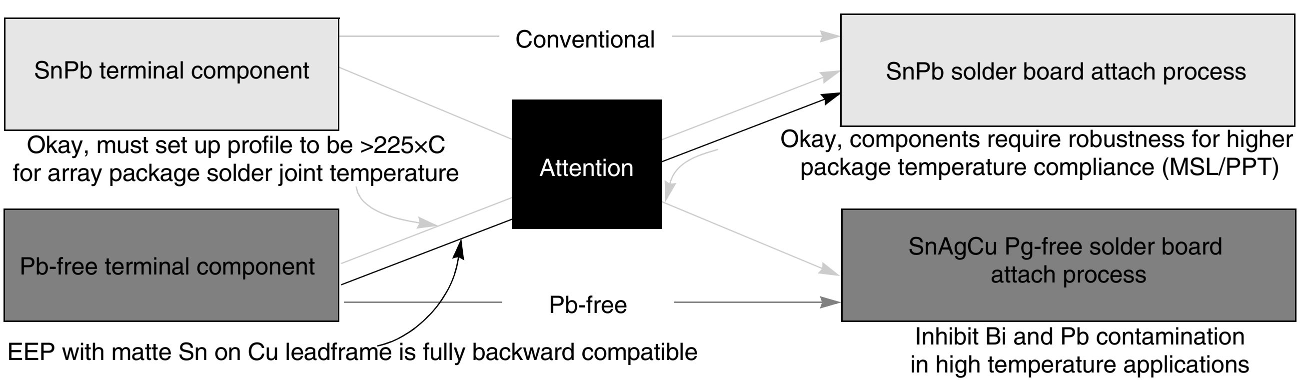

Figure 3. Conditional Forward and Backward Compatibility of SnPb into Pb-free and Vice Versa.

Pb-free board assemblies will typically require extensive changes to the board reflow soldering profile. SnAgCu based solders' melt temperature is approximately 40°C higher than eutectic SnPb-based solders. In addition to these guidelines for the components' processability, it is recommended that Pb-free parts be soldered with solder pastes employing fluxes formulated for the associated higher process temperatures.

Board assemblies have to run a temperature profile matching the solder paste flux requirement. Some flux needs a long dwell time below the temperature of 180°C, but others will burn up in a long dwell. Temperatures out of the solder paste flux recommendations, could result in poor solderability of all components on the board. The solder paste vendor can provide an ideal reflow profile, which gives the best solderability.

Section 4, "Component Soldering with SnPb Solder Paste," and Section 5, "Component Soldering with Pb-Free SnAgCu Solder Paste," give recommendations for component soldering with SnPb pastes respectively with SnAgCu paste

3 Summary

During board assembly it is mandatory to control both the solder joint and the package temperature of components on the printed circuit board. These guidelines do not necessarily indicate the extremes that can safely be applied to surface mount packages. In most cases, the package can withstand higher temperatures than the standard PC board. These guidelines are meant to represent good soldering practices that will yield high quality assemblies with minimum rework.

Solder flux technologies have improved dramatically in recent years and most of the industry uses "no clean" fluxes. Some of these fluxes require specific reflow profiles. These recommendations should always be obeyed precisely, together with the solder joint and package temperature guidelines above.

If semiconductor products are subjected to process temperatures higher than those used for package process certification or product qualification, reliability issues such as popcorn can occur.

4 Component Soldering with SnPb Solder Paste

1. Preheat — Raise temperature of leads/spheres to 100°C for more than a period of no less than 50 seconds.
2. Infrared or convection reflow.

   Products with SnPb or Matte Sn post-plated leadframes form good solder joints under conventional SnPb board soldering conditions and should get SJT dwell time of less than three minutes above the eutectic tin/lead solder melting point of 183°C. Desirable dwell time above 183°C is greater than 50 seconds and less than 80 seconds. SJTs are between 205°C and 220°C.

   Preferably BGAs with SnPbAg solder spheres are recommended for SnPb board soldering with SJTs again in the range of 205–220°C.

   For BGAs with SnAgCu solder spheres, a minimum SJT of 225°C is recommended so the solder volume of SnPb paste and SnAgCu ball do melt in the solder zone while not exceeding any components' specified PPT at any time on the board during soldering.

NOTE

Before assembly verify all components on the PCB can withstand PPT greater than 225°C if assembly is expected to use temperatures above a standard SnPb board assembly process of 225°C.

It is recommended to profile the PPT of critical components on the board.

Existing products that were qualified prior to the release of J-STD-020B in August of 2002 may have only been qualified for a maximum PPT of 225°C.

5 Component Soldering with Pb-Free SnAgCu Solder Paste

Use these guidelines to prevent carrying Bi or Pb into the Pb-free solder joint.

1. Preheat — Raise temperature of leads/spheres to 100°C, for more than a period of no less than 50 seconds.
2. Infrared or convection reflow.

   Minimum SJT to be reached is 235–245°C while not exceeding the specified PPT (240/250/260°C, see J-STD-020C) of any of the components on the board. SJT dwell time of less than three minutes above the solder melt temperature of 217°C. Desirable dwell time above 217°C is greater than 50 seconds and less than 80 seconds.

NOTE

Before assembly verify all components on the PCB can withstand PPT greater than 245°C for Pb-free assemblies (see J-STD-020C).

It is recommended to profile the PPT of critical components on the board.

Existing products that were qualified prior to the release of J-STD-020B in August of 2002 may have only been qualified for a maximum PPT of 225°C.

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