Freescale Semiconductor
Engineering Bulletin

EB635
Rev. 2, 4/2005

Lead-Free BGA Solder Joint Assembly Evaluation

To support a cleaner environment, meet market demands, and comply with international commercial standards and requirements, many integrated circuit devices are migrating to ball-grid array (BGA) packages with lead-free solder spheres consisting of tin/silver/copper alloy. Because the lead-free alloy has a melting temperature of 222°C, which is higher than that of the typical tin/lead alloy melting temperature of 183°C, the solder profile must be examined to determine appropriate manufacturing conditions. This engineering bulletin discusses the characteristics of lead-free sphere BGA packages versus lead-bearing sphere packages and provides general guidelines for reflow soldering using lead-free packages.

CONTENTS

1 Solder Paste Flux 1
2 Lead-Free Sphere Characteristics 2
3 Reflow Solder Assembly Options 2
4 Lead-Free Board Assembly Reflow Profile Example 3
5 Soldering Guidelines for Lead-Free Packages 4

1 Solder Paste Flux

The key factor in determining appropriate reflow temperature is a temperature profile that matches the solder paste flux requirement. Some fluxes require a long dwell time below 180°C, while others burn up with a long dwell time. Out-of-bound solder paste flux temperatures can result in poor solder connections for all components on the board. Obtain the ideal reflow profile, which gives the best solderability, from your solder paste vendor.

© Freescale Semiconductor, Inc., 2004, 2005. All rights reserved.

freescale™ semiconductor

2 Lead-Free Sphere Characteristics

Table 1 compares a standard lead-free sphere to a standard lead-bearing sphere.

Table 1. Lead-Free Versus Lead-Bearing Spheres

Sphere Type	Composition	Solidus Temperature	Liquidus Temperature
Lead-free	95.5Sn4.0Ag0.5Cu	216°C	222°C
Lead-bearing	62Sn36Pb2Ag	179°C	180°C
Note: Composition is listed as % by weight of the listed elements: Sn = tin; Pb = lead; Ag = silver; Cu = copper.			

As shown in **Table 1**, lead-free sphere BGA packages require a higher reflow temperature during soldering than lead-bearing sphere BGA packages, typically 20–40°C hotter. Parts with a moisture sensitivity level (MSL) 3 require a peak reflow of 245–260°C. This value is component dependent—refer to the individual component specifications during the design process to determine the correct value.

3 Reflow Solder Assembly Options

Two options are available for reflow soldering of lead-free sphere BGA packaged components to printed circuit board (PCB) assemblies:

- Tin-based, lead free solder paste (recommended method).
- Traditional lead-bearing solder pastes (such as 63Sn37Pb).

The board reflow procedure may use an infrared (IR) or a convection heating process. For either process, the temperature can vary greatly across the PCB, depending on the furnace type, the size and mass of the board components, and the location of the components on the board. Carefully test profiles to determine the hottest and coolest points on the board. The hottest and coolest points should fall within recommended temperature ranges for the reflow method selected. Carefully attach thermocouples directly to the solder joint interface between the package leads and board using very small amounts of thermally conductive grease or epoxy. 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 PCB. These guidelines are meant to represent good soldering practices that yield high quality assemblies with minimum rework.

3.1 Tin-Based Lead-Free Solder Paste

The 230–245°C peak reflow temperature profiles used with most lead-free solder pastes fully melt the paste and sphere and result in a reliable interconnection.

Note: Before assembly, verify that all components on the PCB can withstand peak reflow temperatures greater than the expected maximum assembly temperature. Existing packages qualified before the release of J-STD-020B in August of 2002 may be qualified only for a maximum peak temperature of 225°C. Subjecting such semiconductor packages to higher reflow temperatures can affect device reliability.

Use the following guidelines when soldering with lead-free solder paste:

1. Preheat the board. Raise the lead/sphere temperature to 100°C over a period of no less than 50 seconds.
2. For infrared or convection reflow, use a peak temperature of 235–245°C. Use a dwell time less than 3 minutes above the solder melting point of 217°C. The optimal dwell time is 50–80 seconds.

3.2 Lead-Bearing Solder Paste

You must use a minimum peak reflow temperature of 220°C to achieve a substantial reflow of the lead-free sphere. Reflow temperatures below 220°C may result in poor assembly yields and inadequate interconnect reliability. For increased margin, use a 225–245°C peak temperature for full reflow with sphere-collapse and reliable interconnection.

Note: Before assembly, verify that all components on the PCB can withstand peak reflow temperatures greater than the expected maximum assembly temperature. Existing packages qualified before the release of J-STD-020B in August of 2002 may be qualified only for a maximum peak temperature of 225°C. Subjecting such semiconductor packages to higher reflow temperatures can affect device reliability.

Use the following guidelines when soldering with lead-bearing paste:

1. Preheat the board. Raise the lead/sphere temperature to 100°C over a period of no less than 50 seconds.
2. For infrared or convection reflow, use a peak temperature of 220–235°C. Use a dwell time of less than three minutes above the eutectic tin/lead solder melting point of 183°C. The optimal dwell time is 50–80 seconds.

4 Lead-Free Board Assembly Reflow Profile Example

Figure 1 shows a typical lead-free board assembly reflow profile.

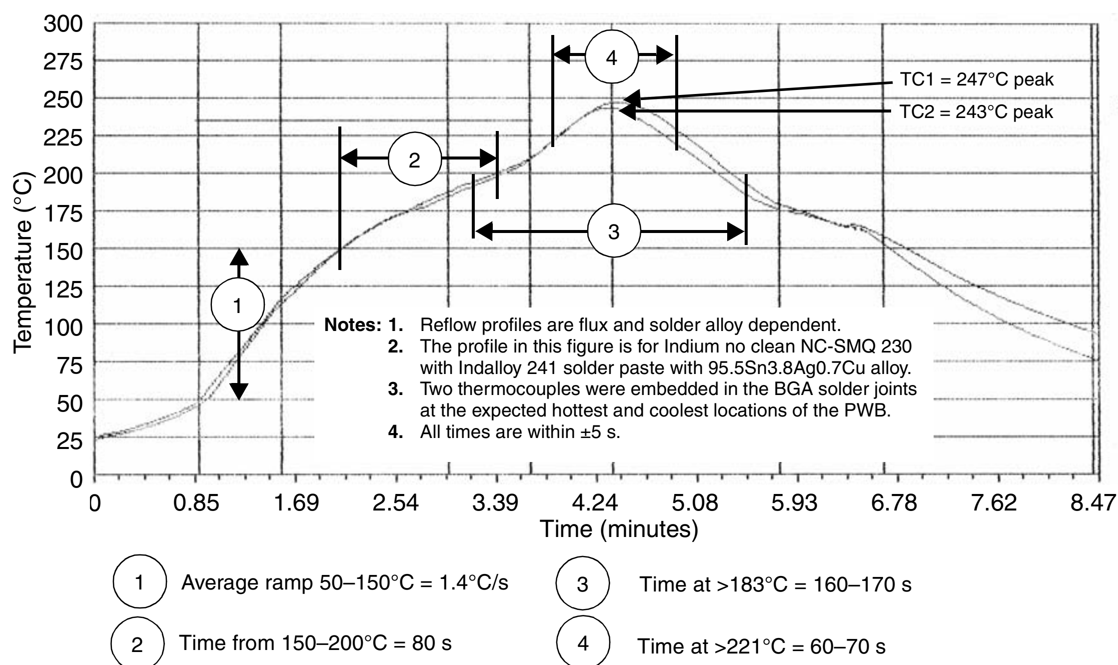

Figure 1. Typical Lead-Free Board Assembly Reflow Profile

5 Soldering Guidelines for Lead-Free Packages

General soldering guidelines for lead-free packages include the following:

- When possible, assemble lead-free BGA packages using lead-free solder paste. Studies demonstrate that lead-free interconnect reliability is similar to or better than lead-bearing devices and solder paste.
- If you must use lead-tin solder paste with lead-free BGA packages, ensure that the reflow temperature is high enough to provide a reliable interconnection. A minimum peak temperature of 220°C is recommended, but a range of 225–245°C (for qualified components) is preferred.
- In all cases, ensure that the correct reflowing profiling and MSL rating is used for all components in the assembly.
- Direct any assembly questions to your component sales office or distributor contact.

How to Reach Us:

Home Page:
www.freescale.com

E-mail:
support@freescale.com

USA/Europe or Locations not listed:
Freescale Semiconductor
Technical Information Center, CH370
1300 N. Alma School Road
Chandler, Arizona 85224
+1-800-521-6274 or +1-480-768-2130
support@freescale.com

Europe, Middle East, and Africa:
Freescale Halbleiter Deutschland GMBH
Technical Information Center
Schatzbogen 7
81829 München, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
support@freescale.com

Japan:
Freescale Semiconductor Japan Ltd.
Headquarters
ARCO Tower 15F
1-8-1, Shimo-Meguro, Meguro-ku,
Tokyo 153-0064, Japan
0120 191014 or +81 3 5437 9125
support.japan@freescale.com

Asia/Pacific:
Freescale Semiconductor Hong Kong Ltd.
Technical Information Center
2 Dai King Street
Tai Po Industrial Estate
Tai Po, N.T. Hong Kong
+800 2666 8080
support.asia@freescale.com

For Literature Requests Only:
Freescale Semiconductor Literature Distribution Center
P.O. Box 5405
Denver, Colorado 80217
1-800-441-2447 or 303-675-2140
Fax: 303-675-2150
LDCForFreescaleSemiconductor@hibbertgroup.com

Information in this document is provided solely to enable system and software implementers to use Freescale Semiconductor products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits or integrated circuits based on the information in this document.

Freescale Semiconductor reserves the right to make changes without further notice to any products herein. Freescale Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Freescale Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. “Typical” parameters which may be provided in Freescale Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including “Typicals” must be validated for each customer application by customer’s technical experts. Freescale Semiconductor does not convey any license under its patent rights nor the rights of others. Freescale Semiconductor products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Freescale Semiconductor product could create a situation where personal injury or death may occur. Should Buyer purchase or use Freescale Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold Freescale Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Freescale Semiconductor was negligent regarding the design or manufacture of the part.

Freescale and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners.

© Freescale Semiconductor, Inc. 2004, 2005.

EB635
Rev. 2
4/2005