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Optimizing Solder Reflow Process for Xilinx BGA Packages

Summary

The primary purpose of solder reflow process is to wet the surfaces to be joined to form a strong metallurgical bond between the component and the PC board.

While the fundamentals of solder reflow process is the same for most applications, careful considerations must be taken for some of the larger and heavier BGA packages.

One of the most significant variables that can affect the package warpage is the solder reflow process. This application note discusses the details of the solder reflow process and provides guidelines on profiling to achieve successful reflow of BGA components.

Reflow Ovens

Full convection ovens are preferred method for BGA assembly. Convection ovens provide more uniform heating and efficient heating across the board and the components. Convection ovens are especially recommended for applications that have a high mixture of components and densely populated boards.

Reflow Process

During the reflow process, the components undergo the following phases as shown in Figure 1.

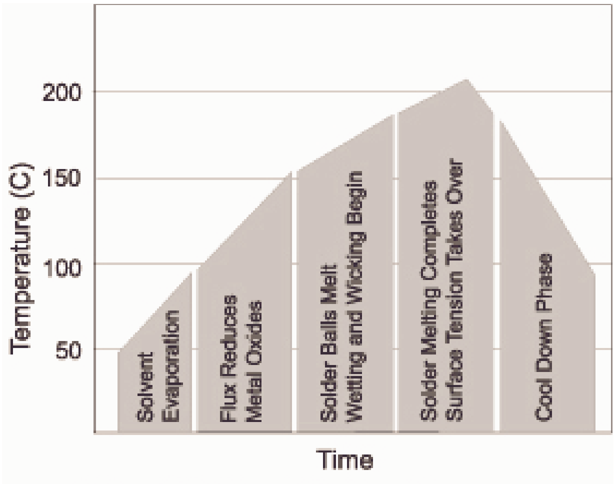

Figure 1: **Reflow Soldering Phases**

As the components go through the five phases (Figure 1) in the oven, several actions take place to prepare a “clean” metal surface suitable for wetting and melting the solder, react with the interfaces, and solidify the solder onto the board. A typical profile with recommended settings for key parameters is shown in Table 1. A graphical representation of the typical profile can be found in Figure 3 in the Appendix.

Table 1: **Process Window for Convection Oven**

Process Steps	Process Description	Process Window
Preheat	Ramp Rate Peak temperature in preheat	1-3°C/sec 100°C-150°C
Preflow	Solder Paste Activation Soak Time	120°C-170°C 60-120 secs
Reflow	Time above 183°C Peak Reflow Temperature Component body temperature	60-120 secs 200°C-210°C 220°C Max
Cool Down	Cooling Rate	1-3°C/sec

Methods of Measuring Profiles

It is important to ensure that proper placement/attachment of thermocouples is carried out in order to accurately measure the desired temperatures. Thermocouples can be attached using either conductive epoxy or high temperature solders. Perhaps the easiest method to attach the thermocouple is by drilling through the pad of the PC board and attaching the thermocouple from the bottom of the PCB directly to the solder ball of the component.

Measurements should be taken at the following locations: center of the solder joint area of the component, the corner of the solder joint area of the component, the top surface of the component, and other components and locations on the PCB.

Reflow Profiling

An optimized profile is paramount in achieving successful reflow result. A good starting point is to refer to the solder paste manufacturer’s suggested reflow profile. However, solder paste manufacturers only supply the basic time/temperature duration information. To get an optimized reflow, components and board characteristics should dictate the maximum temperature and proper ramp rate.

Profiles should be established for all new board designs using thermocouples at multiple locations on the component (top, bottom, and corners-see Figure 2 in the Appendix). In addition, if there are mixture of devices on the board, then the profile should be checked at different locations on the board to ensure that the minimum reflow temperature is reached to reflow the larger components and at the same time, the temperature does not exceed the threshold temperature that may damage the smaller, heat sensitive components. The minimum reflow temperature is the ideal thermal level at which the solder balls can be wetted to form the solder joints.

This information is usually provided by the solder paste manufacturers and it is typically 15-20°C above the solder’s melting point. For eutectic (Sn63Pb37) solder, it is around 200-210°C.

It is critical to keep the temperature gradient across the board as minimal as possible (maintain less than 10°C) to prevent warpage of the components and the board. This is accomplished by using a slower rate in the warm-up and preheating stages. A heating rate of less than 1°C/sec during the initial stage, in combination with a heating rate of not more than 3°C/sec throughout the rest of the profile is highly recommended.

Aside from the board, it is also important to minimize the temperature gradient on the component, between top surface and bottom side, especially during the cool down phase. In fact, cooling is a crucial part of the reflow process and must be optimized accordingly. While a slow cooling rate may result in high assembly yields, it could lead to formation of thick intermetallic layers with large grain size; thereby, reducing the solder joint strength. On the other hand, faster cooling rate leads to smaller solder joint grain size, and hence resulting in higher solder joint fatigue resistance. However, overly aggressive cooling on stiff packages with large thermal mass such as flip chip BGAs may lead to cracking or package warpage because of the differential cooling effects between the top surface and bottom side of the component and between the component and the PCB materials.

The key is to have an optimized cooling with minimal temperature differential between the top surface of the package and the solder joint area. The temperature differential between the top surface of the component and the solder balls should be maintained at less than 7°C during the critical region of the cool down phase of the reflow process. This critical region is the phase in which the balls are not completely solidified to the board yet, usually between the 180°C-160°C range. The best solution may be to divide the cooling section into multiple zones, with each zone operating at different temperatures to efficiently cool the parts.

References

1. Gilleo, Ken, "Area Array Packaging Handbook", copyrighted 2002 by McGraw-Hill Co., pages 14.14-14.16.
2. Hall, James, "Concentrating on Reflow's Cooling Zones", EP&P, 3/01/2001.
3. Narrow, Phil, "Soldering", SMT Magazine, Aug. 2000.

Appendix

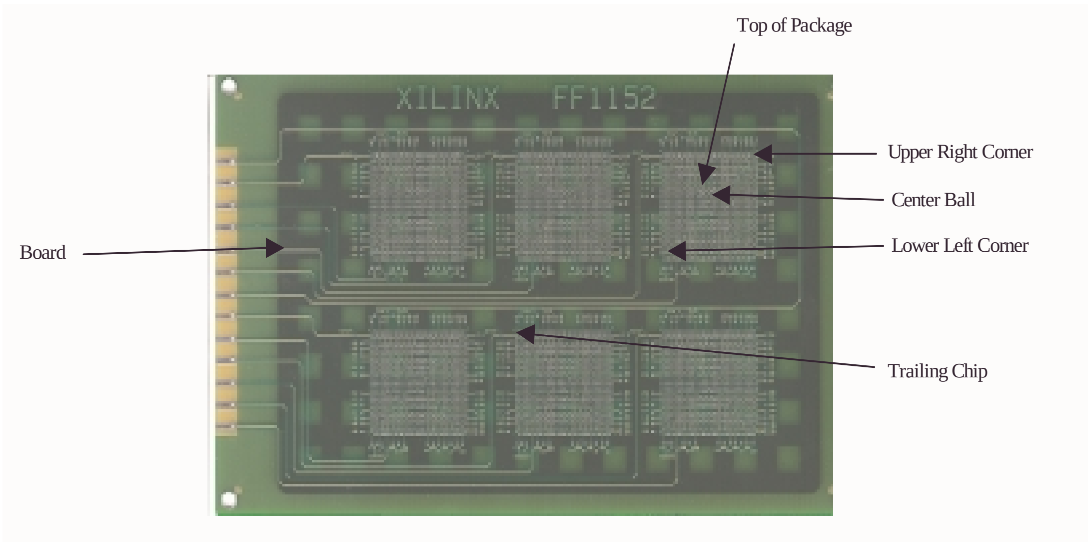

Figure 2: **Temperature Measurement Locations**

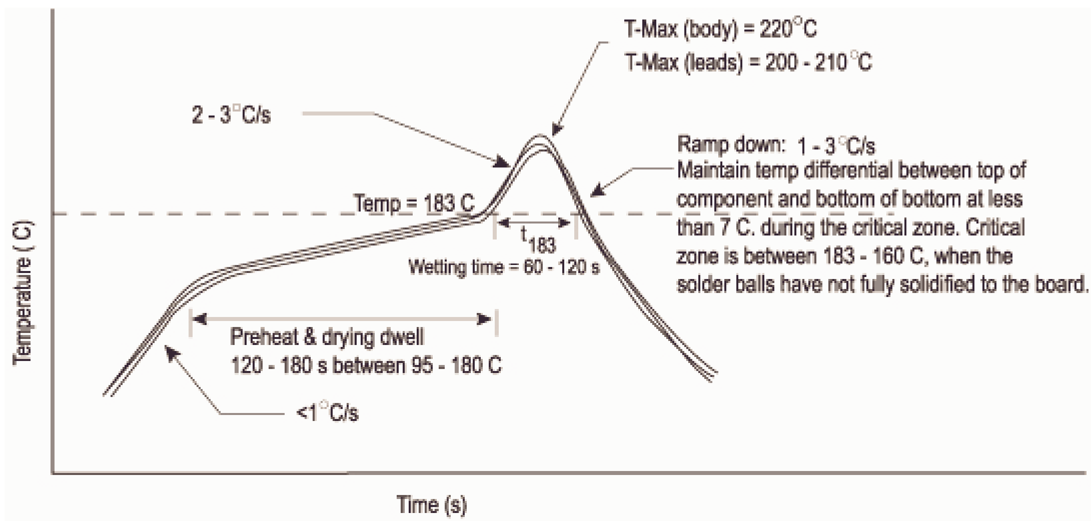

Figure 3: **Typical Solder Reflow Profle for BGA**

Revision History

The following table shows the revision history for this document.

Date	Version	Revision
12/09/02	1.0	Initial Xilinx release.