

## Introduction

Altera's surface-mount products include quad flat pack (QFP), ceramic and plastic J-lead chip carriers (JLCC and PLCC, respectively), ball-grid array (BGA), including FineLine BGA™, and small-outline integrated circuit (SOIC) devices, as well as QFP development sockets. Several soldering methods exist for these devices, but forced-air convection and infrared reflow soldering (or a hybrid) are the most common ways to secure surface-mount technology (SMT) devices to printed circuit boards (PCBs). These reflow processes consist of applying a eutectic solder paste to a circuit board, placing devices onto the paste, and then conveying the board through an oven with successive heating elements of varying temperatures. In the oven, each board typically passes through a gradual preheating stage followed by a brief duration at the higher soldering temperature. The maximum temperature, the rate of heating, and the time a device spends at each temperature are the most critical parameters for effective soldering.

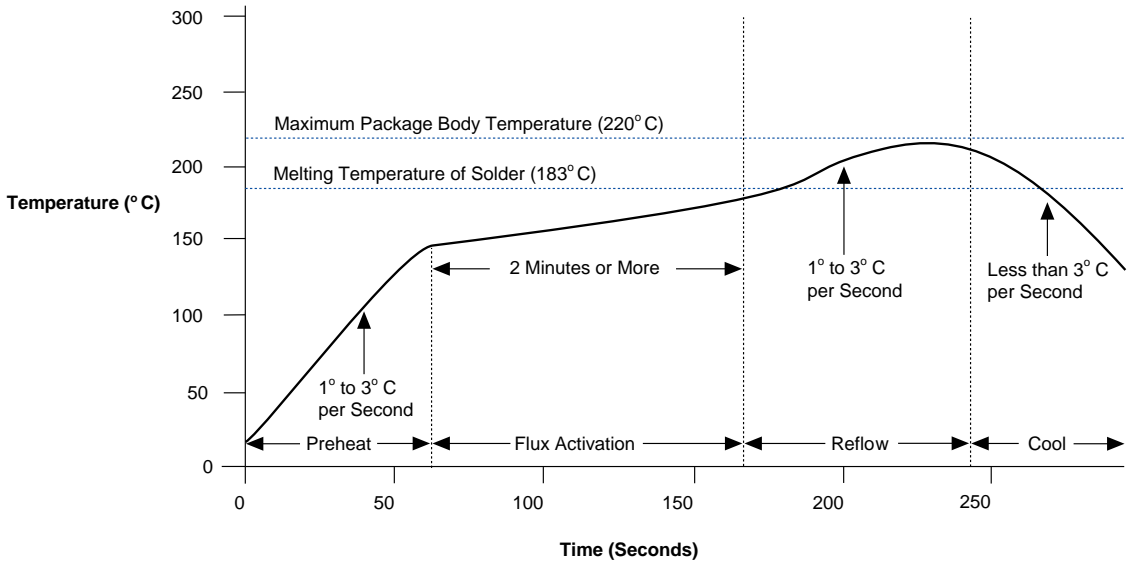
Customers' experiences have shown that Altera® surface-mount products can be mounted successfully on boards over a wide range of temperatures. Any plastic package, especially if it is sensitive to moisture, can be damaged by an inappropriate reflow process. Although Altera does not perform board assembly, guidelines for reflow processes have been developed. These guidelines are based on extensive experiments that subject Altera devices to the controlled introduction of moisture, simulation of infrared and vapor-phase reflow, and temperature cycling. Altera cannot specify a universally optimal temperature profile without knowing each customer's board design, application, and available equipment. However, the following recommendations do provide adequate guidelines and limits to ensure that devices are not unduly stressed.

## Temperature Profiles

Because different board designs use different number and types of devices, solder paste, and circuit boards, no single temperature profile works for all PCBs. However, [Figure 1](#) shows a sample temperature profile based on successful profiles used by Altera. The graph illustrates the four basic stages of a reflow oven:

- Preheat
- Flux Activation
- Reflow
- Cool

Figure 1. Temperature Profile for Infrared or Convection Reflow



## Reflow Stages

In the preheat stage, the solder paste dries while its more volatile ingredients evaporate. After preheating, the leads should be kept at about 150° C for a minimum of two minutes so the flux in the paste can clean the bonding surfaces properly. During the flux activation stage, the solder on all areas of the board should be roughly the same temperature. The devices enter the reflow stage when the temperature increases at a rate of 1° to 3° C per second. To prevent warping, bridging, and cold solder joints, keep the leads above the solder’s melting point (about 183° C) for at least 60 seconds. Ideally, the leads should only be subjected to the peak temperature (220° C) for approximately 10 seconds to reduce the risk of damage to the solder and devices. In addition, the device body temperature—which may vary from the temperature of the leads by as much as 15° C—should not exceed 220° C.

## Post-Reflow Cooling

The reflow stage is complete when the molten solder connections cool and solidify to form strong solder joint fillets. A fast cooling rate reduces the grain size of the intermetallic compounds and strengthens the solder joints. However, due to the risk of thermal shock, cooling should be less than 3° C per second.

## Post-Reflow Cleaning

After the soldering process, a simple wash with de-ionized water sufficiently removes most residue from the board. Most board-assembly manufacturers use either water-soluble fluxes with a tap water wash, or “no-clean” fluxes that do not require cleaning after reflow.

## Reflow Tips

The following tips provide information on how to optimize the reflow process:

- For more uniform heating, use convection and hybrid ovens rather than plain, infrared ovens. Some boards (especially those with large devices or sockets) require fine-tuned ovens that provide uniform temperatures to all devices on the board.
- Use an oven with more heating elements on both its floor and ceiling to minimize temperature variations, deliver precise temperature, and provide the necessary heat to board areas that might be shielded.
- Place thermocouples on the leads and bodies of the devices. Monitor the lead temperatures to ensure good solder joints, and monitor the device body temperatures to protect the devices. The difference between the lead and device body temperatures can be as high as 15° C. Therefore, it is risky to rely on temperature measurements at only one location. Thermocouples should not be applied to heatsinks, but to alternative surfaces such as the package substrate or the PCB board immediately adjacent the package.
- Adjust the reflow duration to create good solder joints without raising the device body temperature beyond the allowed maximum of 220° C.

## Moisture-Sensitivity of Devices

Semiconductor moisture sensitivity becomes an important issue as board assemblers switch to hotter and faster reflow processes. Any non-hermetic package can absorb moisture. Like popcorn, the moisture in some plastic packages can vaporize and expand rapidly due to high temperatures causing cracks or delamination (a slight separation of the plastic from the die or leadframe inside a device). Delamination sometimes, but not always, degrades devices.

Altera is dedicated to improving package materials to reduce the risk of moisture-induced damage. Nevertheless, as a precaution, Altera currently bakes and dry-packs devices in the following package families (these are plastic surface mount packages that may require dry-pack, depending on the number of leads and the device):

- Thin quad flat pack (TQFP)
- Power quad flat pack (RQFP)
- Plastic quad flat pack (PQFP)
- Plastic J-lead chip carrier (PLCC)
- Ball-grid array (BGA), including FineLine BGA

Based on the sensitivity of each device to moisture, Altera has specified the floor life of each package, which is the maximum recommended time between removing devices from a dry pack and soldering them onto a PCB. To determine the floor life for each moisture-sensitive device, Altera forced moisture into sample packages, then subjected them to typical reflow temperatures and temperature cycling. The devices were subsequently tested electrically and analyzed physically with x-ray and acoustic microscopy to gauge their sensitivity to moisture. Altera performs moisture sensitivity tests according to *Procedures for Characterizing & Handling of Moisture-/Reflow-Sensitive ICs* (IPC-SM-786A), the standard from the Institute for Interconnecting and Packaging Electronic Circuits, and *Moisture/Reflow Sensitivity Classification for Non-Hermetic Solid State Surface Mount Devices* (J-STD-020A). Reliability and solder tests demonstrated that 220° C is both a satisfactory and safe maximum body temperature for Altera devices during reflow (i.e., 220° C is adequate for soldering devices onto PCBs *and* 220° C is the maximum safe temperature).

Altera provides a broad range of packages, pin counts, and device sizes. While this variety provides convenient options for designers, it precludes Altera's ability to specify one level of sensitivity per package type. For instance, QFP packages with a larger die or pin count tend to be more sensitive to moisture than QFP packages with smaller die or pin count. Therefore, Altera tests the sensitivity of packages by using representative devices with a variety of die sizes, die shapes, and pin count. (Although similar packages tend to have similar sensitivity, all devices in a particular package rarely have the same floor life.) Based on the tests of the representative devices, Altera specifies the sensitivity of each device and package combination. However, designers should refer to the dry-pack labels, which have the most current and reliable information about a device's sensitivity to moisture. When transferring devices to new dry-pack bags, operators should carefully copy the floor life and expiration date onto the new dry-pack labels.

## Reflow of Moisture-Sensitive Devices



Once the moisture-sensitive devices are removed from their dry-pack bags or other controlled environments, the devices should be soldered onto a PCB within the floor life specified on the dry-pack label. Devices can be stored indefinitely in a desiccant cabinet, which is a controlled environment kept at less than 30° C and 20% relative humidity. If a device is over-exposed to moisture, bake it for 12 hours at 125° C to dry it, then mount the device within the specified floor life.

For more information about storing and handling moisture-sensitive devices, see [Application Note 71 \(Guidelines for Handling J-Lead, QFP & BGA Devices\)](#).

During reflow, the device's temperature should be kept below 220° C, and the rate of temperature change should be kept between 1° to 3° C per second. Based on testing done by Altera, the devices can operate safely at any humidity level after reflow.

## Guidelines for Removing SMT Devices

When the soldering process is complete, you may need to rework or remove SMT devices from PCBs. Although Altera devices are designed for ease-of-use, you should be careful when separating them from PCBs. Careless heating or removal of a plastic package can cause thermal and lead damage. These degradations may render a device useless, impeding any failure analysis and preventing the reuse of the device. Therefore, it is important to observe the thermal and lead damage precautions outlined in this section.

### Preventing Thermal Damage

Removing SMT devices requires guidelines similar to those for soldering parts. The temperature, rate of heating, and time a device spends at each temperature are the most critical parameters for effective soldering. These thermal guidelines are also important when removing devices from PCBs—whether you use an oven, heat gun, or soldering iron. Most importantly, you should ensure that the temperature of the plastic packages does not exceed 220° C. By adjusting the duration of heating, you can safely remove devices in almost all cases without raising the temperature of the package body beyond 220° C.

To prevent thermal damage, follow these guidelines:

- Place thermocouples on the leads and body of a device. You should monitor the leads' temperature to ensure clean removal of solder and the package body temperature to protect the device. The difference between the lead and device body temperatures should be no higher than 15° C. Therefore, it is risky to rely on temperature measurements at only one location. Thermocouples should not be applied to

heatsinks, but to alternative surfaces such as the package substrate or the PCB board immediately adjacent to the package.

- When heated, some plastic devices are especially sensitive to moisture, which can quickly expand and irrevocably destroy devices. After reflow, based on Altera's testing, even these devices can operate safely in any level of humidity. If a device has been exposed to too much moisture, bake it for 12 hours at 125° C to dehydrate it, and then remove it from the board within five days (one day for RQFPs). If all moisture-sensitive devices on the board are within the original specified floor-life times, baking is unnecessary.

### Preventing Lead Damage

Although Altera uses industry-standard materials and assembly processes for QFP, SOIC, and J-lead packages, you should handle SMT devices carefully to prevent lead damage, which can cause solder-related problems. In addition, extreme temperatures can damage the solder plating (i.e., by oxidation), and solder from the PCB may remain on leads and cause shorts by bridging. To prevent these types of lead damage, you should ensure that the leads are heated for the right amount of time at a uniform temperature before removing a device. The actual temperatures and durations depend on the heating tools and methods, which require some experimentation.

To prevent lead damage, follow these guidelines:

- Place thermocouples on the leads and bodies of the devices. You should monitor the leads' temperature to ensure clean removal of solder and the package body's temperature to protect the parts. The difference between the lead and device body temperatures can be as high as 15° C. Therefore, it is risky to rely on temperature measurements at only one location.
- Once the solder on the PCB is sufficiently heated, use a vacuum pen to lift a device straight up off a PCB. Avoid twisting or rotating the device while removing it. Also, do not touch or cut leads if the device will be reused or returned to Altera for failure analysis.
- Soon after removing a device from a PCB, wash it with de-ionized water to remove excess solder and residues.
- Using a vacuum pen, immediately transfer removed QFPs to an Altera-approved, Peak-manufactured tray. Ensure that each device sits in the tray correctly.



For more information on Peak-manufactured trays, see [Application Note 71 \(Guidelines for Handling J-Lead, QFP & BGA Devices\)](#).

## References

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