# Solder Reflow Guide for Surface Mount Devices

## Technical Note

FPGA-TN-02041-4.2

October 2020

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# Acronyms in This Document

A list of acronyms used in this document.

| Acronym | Definition |
|---|---|
| BGA | Ball Grid Array |
| caBGA | Chip Array BGA, 0.80 mm Ball Pitch |
| ckfBGA | Flip Chip BGA 7x7 mm Body Size, 0.65 mm Ball Pitch |
| csBGA | Chip-Scale BGA, 0.50 mm Ball Pitch |
| ctfBGA | Flip Chip BGA, 0.65 mm Ball Pitch |
| DI | Deionized |
| fcBGA | Flip Chip BGA, ≥ 0.80 mm Ball Pitch |
| fpBGA | Fine Pitch BGA, ≥ 1.00 mm Ball Pitch |
| fpSBGA | Cavity Down, Thermally Enhanced Ball Grid Array, 1.00 mm Ball Pitch |
| ftBGA | Fine Pitch Thin BGA,  = 1.00 mm Ball Pitch |
| IPC | Association Connecting Electronics Industries |
| JEDEC | JEDEC Solid State Technology Association |
| JLCC | J-leaded Ceramic Chip Carrier |
| LCC | Leadless Chip Carrier |
| LQFP | Low-Profile Quad Flat Pack, 1.4mm Thick |
| PCB | Printed Circuit Board |
| PDIP | Plastic Dual-in-Line Package |
| PLCC | Plastic Leaded Chip Carrier |
| PQFP | Plastic Quad Flat Pack |
| PPM | Parts per million |
| QFN | Quad Flat Package Punched Singulation |
| QFNS | Quad Flat Package Saw-Singulated |
| RoHS | Restriction of Use of Hazardous Substances |
| SBGA | Super BGA, ≥ 1.00 mm Ball Pitch |
| SMT | Surface-Mount Technology (Assembling and Mounting Technology) |
| SSOP | Shrink, Small Outline Package |
| TQFP | Thin Quad Flat Pack, 1.0mm Thick |
| TS | Technical Specification |
| ucBGA | Ultra Chip-Scale BGA, 0.40 mm Ball Pitch |
| ucfBGA | Ultra Chip Flip Chip BGA, 0.40mm Ball Pitch |
| WLCSP | Wafer Level Chip Scale Package |

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# 1. Introduction

This technical note provides general guidelines for solder reflow and rework process for Lattice Semiconductor surface mount products. The data used in this document is based on IPC/JEDEC (Association Connecting Electronics Industries/JEDEC Solid State Technology Association) standards. Each board has its own profile which depends upon the reflow equipment used and the board design. The PCB (printed circuit board) must be individually characterized to find the reliable profile. This document covers Sn/Pb (Tin/Lead), Pb-Free (Lead-Free), and Halogen-Free processes.

# 2. Reflow

- Use caution when profiling to insure that the maximum temperature difference between components is less than 10 °C (7 °C within an individual component).
- Forced convection reflow with nitrogen is preferred (with maximum oxygen content of 50-75 PPM). Select an appropriate heat sink and thermal interface material for the package.

# 3. Inspection

- Pre-reflow – Use visual inspection to verify solder paste dispense location and quantity.
- Pick and place – Use machine vision as necessary to ensure proper component placement.
- Post reflow – Use electrical testing to verify solder joint formation (100% post-reflow visual inspection is not recommended).

# 4. Cleaning Recommendations

- After solder reflow, printed circuit boards should be thoroughly cleaned and dried using standard cleaning equipment.
- Final rinse should be warm deionized (DI) water (50 °C to 75 °C) with resistivity of 0.2 MΩ /cm or greater.
- After cleaning, the boards should be baked for a minimum of one hour at 125 °C to evaporate residual moisture.

# 5. Rework Recommendations

Removal and replacement of SMT (surface-mount technology) packages on PCBs is fairly straightforward. However, reattachment or touch-up of SMT packages that have already been soldered to the board is not practical in most cases.

A few important criteria should be considered when choosing a rework system:

- Minimize the change in temperature across the solder joint array to promote good solder joint formation, minimize intermetallic growth, improve solderability and minimize component warpage.
- Minimize die temperature to prevent die delamination and wire bond failure.
- Minimize board temperature adjacent to the rework site to reduce intermetallic growth, prevent secondary reflow, and prevent possible component delamination.
- For boards with no internal ground plane, apply localized heat to the SMT package. When the solder is molten, remove package using appropriate vacuum tool.
- While the board is still hot, remove excess solder from the site using a vacuum desoldering system or a soldering iron and solder wicking material. Use care to avoid damaging the solder pads or the surrounding solder mask.
- For PCBs with internal ground plane(s), preheat the entire board to at least 80 °C before removing the SMT packages.
- Use alcohol to remove residual flux, then wash the entire board using the standard board cleaning process before attempting to replace SMT components.

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# 6. BGA Reballing

BGA reballing is not recommended. Reballed BGA packages void the original Lattice specifications.

# 7. Pb-Free/Halogen-Free (RoHS-Compliant) Products

All Lattice Pb-Free products are also fully RoHS compliant. Similarly, all Lattice Halogen-free products are also Pb-Free and RoHS compliant. Lattice offers a broad range of Pb-Free and Halogen-Free (RoHS-compliant) products in a variety of package configurations. These packages include the Thin Quad Flat Pack (TQFP), Quad Flat Pack Saw-Singulated (QFNS), Fine Pitch BGA (fpBGA), Thin BGA (ftBGA), Chip-Scale BGA (csBGA), Ultra Chip-Scale BGA (ucBGA), Chip Array BGA (caBGA) and Flip Chip BGA (fcBGA), Chip Array BGA (caBGA), Flip Chip BGA (fcBGA) and Wafer Level Chip Scale Package(WLCSP).

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# 8. Peak Reflow Temperature (TP) by Package Size

Table 8.1. illustrates the peak reflow temperatures by package size. Refer to the Package Diagrams document and use maximum package dimensions to determine package thickness and volume which is computed as [D*E*(Amax-A1min)].

**Table 8.1. Peak Reflow Temperature (TP)**

| Classification | Package Thickness | Volume < 350 mm$^3$. | Volume = 350–2000 mm$^3$. | Volume > 2000 mm$^3$. |
|---|---|---|---|---|
| SnPb Package | < 2.5 mm | 235 + 0/–5 °C | 220 + 0/–5 °C | |
| | ≥ 2.5 mm | 220 + 0/–5 °C | | |
| Pb-Free and Halogen- Free Packages | < 1.6 mm | 260 + 0/–5 °C | | |
| | 1.6 mm to ≤ 2.5 mm | 260 + 0/–5 °C | 250 + 0/–5 °C | 245 + 0/–5 °C |
| | > 2.5 mm | 250 + 0/–5 °C | 245 + 0/–5 °C | |

**Notes:**

1. Package volume excludes external terminals (balls, bumps, lands, leads) and non-integral heat sinks.
2. Based on J-STD-020E_Moisture Reflow Sensitivity Classification

Table 8.2. shows the peak reflow temperature for Lattice devices by package type and size.

**Table 8.2. Peak Reflow Temperature (TP) by Package Type and Size**

| Package Type | Number of Lead/Balls | SnPb Package | | Pb-Free / Halogen-Free Package (RoHS Compliant) | |
|---|---|---|---|---|---|
| | | Moisture Sensitivity Level | Peak Reflow Temp. (+0/–5 °C) | Moisture Sensitivity Level | Peak Reflow Temp. (+0/–5 °C) |
| caBGA | 49 | 3 | 235 | Package not offered | |
| | 100 | 3 | 235 | 3 | 260 |
| | 121 | Package not offered | | 3 | 260 |
| | 196 | Package not offered | | 3 | 260 |
| | 256 | 3 | 235 | 3 | 260 |
| | 324 | Package not offered | | 3 | 260 |
| | 332 | Package not offered | | 3 | 250 |
| | 381 | Package not offered | | 3 | 260 |
| | 400 | Package not offered | | 3 | 260 |
| | 484 | Package not offered | | 3 | 260 |
| | 554 | Package not offered | | 3 | 260 |
| | 756 | Package not offered | | 3 | 260 |
| csBGA | 56 | 3 | 235 | 3 | 260 |
| | 64 | Package not offered | | 3 | 260 |
| | 81 | Package not offered | | 3 | 260 |
| | 100 | 3 | 235 | 3 | 260 |
| | 121 | Package not offered | | 3 | 260 |
| | 132 | 3 | 235 | 3 | 260 |
| | 144 | Package not offered | | 3 | 260 |
| | 184 | Package not offered | | 3 | 260 |
| | 196 | 3 | 235 | 3 | 260 |
| | 284 | 3 | 235 | 3 | 260 |
| | 289 | Package not offered | | 3 | 260 |
| | 328 | Package not offered | | 3 | 260 |
| ckfBGA | 80 | Package not offered | | 3 | 260 |
| ctfBGA | 80 | Package not offered | | 3 | 260 |

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| Package Type | Number of Lead/Balls | SnPb Package | | Pb-Free / Halogen-Free Package (RoHS Compliant) | |
|---|---|---|---|---|---|
| | | Moisture Sensitivity Level | Peak Reflow Temp. (+0/–5 °C) | Moisture Sensitivity Level | Peak Reflow Temp. (+0/–5 °C) |
| csfBGA | 81 | Package not offered | | 3 | 260 |
| | 121 | Package not offered | | 3 | 260 |
| | 256 | Package not offered | | 3 | 260 |
| | 285 | Package not offered | | 3 | 260 |
| | 324 | Package not offered | | 3 | 260 |
| ucBGA | 36 | Package not offered | | 3 | 260 |
| | 49 | Package not offered | | 3 | 260 |
| | 64 | Package not offered | | 3 | 260 |
| | 81 | Package not offered | | 3 | 260 |
| | 121 | Package not offered | | 3 | 260 |
| | 132 | Package not offered | | 3 | 260 |
| | 225 | Package not offered | | 3 | 260 |
| ucfBGA | 36 | Package not offered | | 3 | 260 |
| | 64 | Package not offered | | 3 | 260 |
| fcBGA | 484 | Package not offered | | 4 | 250 |
| | 676 | 4 | 220 | 4 | 245 |
| | 1020 | 4 | 220 | 4 | 245 |
| | 1152 | 4 | 220 | 4 | 245 |
| | 1704 | 4 | 220 | 4 | 245 |
| fpBGA | 100 | 3 | 235 | 3 | 260 |
| | 144 | 3 | 235 | 3 | 260 |
| | 208 | 3 | 220 | 3 | 250 |
| | 256 | 3 | 220 | 3 | 250 |
| | 272 | 3 | 220 | 3 | 250 |
| | 388 | 3 | 220 | 3 | 250 |
| | 416 | 3 | 220 | Package not offered | |
| | 484 | 3 | 220 | 3 | 250 |
| | 516 | 3 | 220 | Package not offered | |
| | 672 | 3 | 220 | 3 | 250 |
| | 676 | 3 | 220 | Package not offered | |
| | 680 | 3 | 220 | 3 | 245 |
| | 900 | 3 | 220 | 3 | 245 |
| | 1152 | 3 | 220 | 3 | 245 |
| | 1156 | 3 | 220 | 3 | 245 |
| fpSBGA | 680 | 3 | 220 | Package not offered | |
| ftBGA | 208 | Package not offered | | 3 | 260 |
| | 237 | Package not offered | | 3 | 260 |
| | 256[1] | 3 | 220 | 3 | 260 |
| | 256[2] | 3 | 220 | 3 | 250 |
| | 324 | 3 | 220 | 3 | 260 |

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| Package Type | Number of Lead/Balls | SnPb Package | | Pb-Free / Halogen-Free Package (RoHS Compliant) | |
|---|---|---|---|---|---|
| | | Moisture Sensitivity Level | Peak Reflow Temp. (+0/–5 °C) | Moisture Sensitivity Level | Peak Reflow Temp. (+0/–5 °C) |
| LQFP | 44 | 3 | 235 | 3 | 260 |
| | 48 | 3 | 235 | 3 | 260 |
| | 64 | 3 | 235 | 3 | 260 |
| | 100 | 3 | 235 | 3 | 260 |
| | 128 | 3 | 235 | 3 | 260 |
| | 144 | 3 | 220 | 3 | 260 |
| | 176 | 3 | 220 | 3 | 260 |
| TQFP | 44 | 3 | 235 | 3 | 260 |
| | 48 | 3 | 235 | 3 | 260 |
| | 100 | Package not offered | | 3 | 260 |
| | 388 | 3 | 220 | Package not offered | |
| PLCC | 20 | 1 | 235 | 1 | 260 |
| | 28 | 1 | 235 | 1 | 260 |
| | 44 | 3 | 235 | 3 | 260 |
| | 68 | 3 | 235 | Package not offered | |
| | 84 | 3 | 235 | 4 | 260 |
| PQFP | 100 | 3 | 220 | 3 | 245 |
| | 120 | 3 | 220 | Package not offered | |
| | 128 | 3 | 220 | 3 | 245 |
| | 160 | 3 | 220 | 3 | 245 |
| | 208 | 3 | 220 | 3 | 245 |
| QFNS | 24 | Package not offered | | 1 | 260 |
| | 32 | 1 | 235 | 1 | 260 |
| | 48 | Package not offered | | 3 | 260 |
| | 64 | Package not offered | | 3 | 260 |
| | 84 | Package not offered | | 3 | 260 |
| QFN | 72 | Package not offered | | 3 | 260 |
| SBGA | 256 | 3 | 220 | Package not offered | |
| | 320 | 3 | 220 | Package not offered | |
| | 352 | 3 | 220 | Package not offered | |
| | 432 | 3 | 220 | Package not offered | |
| SSOP | 28 | 1 | 235 | Package not offered | |
| WLCSP | 16 | Package not offered | | 1 | 260 |
| | 25 | Package not offered | | 1 | 260 |
| | 30 | Package not offered | | 1 | 260 |
| | 36 | Package not offered | | 1 | 260 |
| | 49 | Package not offered | | 1 | 260 |
| | 72 | Package not offered | | 1 | 260 |
| | 81 | Package not offered | | 1 | 260 |
| LCC | 20 | 1 | 235 | Package not offered | |
| | 28 | 1 | 235 | Package not offered | |
| PDIP | 20 | 1 | 235 | 1 | 260 |
| | 24 | 1 | 235 | 1 | 260 |
| | 28 | 1 | 235 | 1 | 260 |

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| Package Type | Number of Lead/Balls | SnPb Package | | Pb-Free / Halogen-Free Package (RoHS Compliant) | |
|---|---|---|---|---|---|
| | | Moisture Sensitivity Level | Peak Reflow Temp. (+0/–5 °C) | Moisture Sensitivity Level | Peak Reflow Temp. (+0/–5 °C) |
| JLCC | 44 | 3 | 235 | Package not offered | |
| | 68 | 3 | 235 | Package not offered | |
| GLQFP | 128 | Package not offered | | 3 | 260 |

**Notes:**

1. ispMACH® 4000, MachXO2™, MachXO™, LatticeXP2™
2. LatticeECP3™

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# 9. Reflow Profile for SMT Packages

The typical reflow process includes four phases.

1. Preheat – Brings the assembly from 25 °C to TS. During this phase the solvent evaporates from the solder paste. Preheat temperature ramp rate should be less than 2 °C/second to avoid solder ball spattering and bridging.
   - Solder Ball Spattering – The most common solder balling defect is spattering which is caused by explosive evaporation of solvents. It can be eliminated by a slower temperature rise in the preheat phase.
   - Bridging – Often seen on fine pitch components and usually caused by inaccurate or splashy screen printing. But it can also be a result of solder paste slumping caused by rapid temperature rise in the pre- heat phase.
2. Flux Activation – The temperature rises slowly and reaches a point at which the flux completely wets the surfaces to be soldered.
3. Reflow – In this phase, the temperature rises to a level sufficient to reflow the solder. The flux wicks surface oxides and contaminants away from the melted solder, resulting in a clean solder joint.
4. Cool Down – Ramp down rate should be as fast as possible in order to control grain size, but should not exceed 6 °C/second.

Table 9.1 and Figure 9.1 describe the reflow profile.

**Table 9.1. Peak Reflow Temperature (TP)**

| Parameter | Description | SnPb Package | Pb-Free and Halogen-Free Packages |
|---|---|---|---|
| Ramp-Up | Average Ramp-Up Rate ($T_{SMAX}$ to $T_P$) | 3 °C/second max. | 3 °C/second max. |
| $T_{SMIN}$ | Preheat Peak Min. Temperature | 100 °C | 150 °C |
| $T_{SMAX}$ | Preheat Peak Max. Temperature | 150 °C | 200 °C |
| $t_S$ | Time between $T_{SMIN}$ and $T_{SMAX}$ | 60 seconds–120 seconds | 60 seconds–120 seconds |
| $T_L$ | Solder Melting Point | 183 °C | 217 °C |
| $t_L$ | Time Maintained above $T_L$ | 60 seconds–150 seconds | 60 seconds–150 seconds |
| $t_P$ | Time within 5 °C of Peak Temperature | 10 seconds–30 seconds | 30 seconds |
| Ramp-Down | Ramp-Down Rate | 6 °C/second max. | 6 °C/second max. |
| t 25 °C to $T_P$ | Time from 25 °C to Peak Temperature | 6 minutes max. | 8 minutes max. |

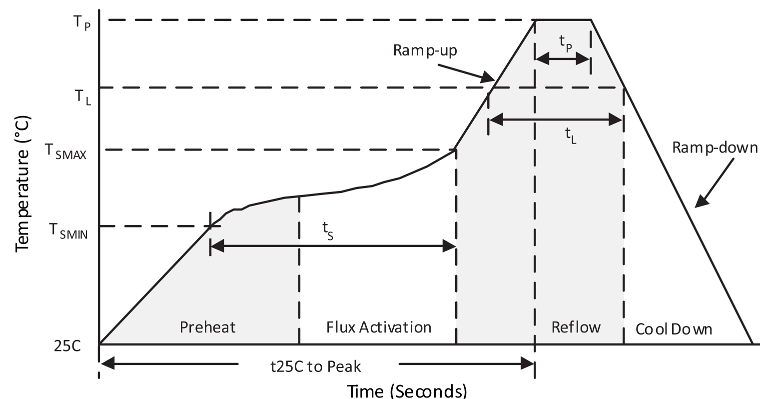


**Figure 9.1. Thermal Reflow Profile**

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# Revision History

### Revision 4.2, June 2020

| Section | Change Summary |
| --- | --- |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2 to include 484 in fcBGA package type. |

### Revision 4.1, August 2020

| Section | Change Summary |
| --- | --- |
| Acronyms in This Document | Updated content. |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2 based on JEDEC reflow profile requirement.<br>• Peak Reflow Temps were brought in line with current JEDEC standards and corresponding package volume per package diagram.<br>• Added Reflow profile requirement of 121caBGA, 196csBGA, 284csBGA, 64ucfBGA, 676fcBGA, 237ftBGA, 44LQFP, 72QFN, 72WLCSP, LCC, PDIP, JLCC, and GLQFP to align with the packages included in the Package Diagram document.<br>• Added 289csBGA new package.<br>• Changed TQFP 1.4mm to LQFP to align with Lattice standard package code<br>• Deleted 36QFN, 20WLCSP, 256BGA, and 352BGA – not included in the Package Diagram document and no data in Agiloft.<br>• Removed Options/Notes of the same number of leads/balls if Reflow Profile requirement is the same.<br>• Not Available is changed to Package Offered |

### Revision 4.0, June 2020

| Section | Change Summary |
| --- | --- |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2 to add 484 and 196 for caBGA package type. |

### Revision 3.9, May 2020

| Section | Change Summary |
| --- | --- |
| Disclaimers | Added this section. |
| Acronyms in This Document | Updated this table. |
| Peak Reflow Temperature (TP) by Package Size | • Updated Table 8.1.<br>• Updated Table 8.2 to add package type for Snow80. |
| Revision History | Updated format. |

### Revision 3.8, November 2017

| Section | Change Summary |
| --- | --- |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2. Peak Reflow Temperature (TP) by Package Type and Size. Changed Moisture Sensitivity Level value for csfBGA 285 Balls from 5 to 3. |
| All | • Changed document ID from TN1076 to FPGA-TN-02041.<br>• Updated document template.<br>• Applied minor editorial changes. |
| Acronyms in This Document | • Added Acronyms in This Document section. |

### Revision 3.7, January 2017

| Section | Change Summary |
| --- | --- |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size.<br>• Changed Moisture Sensitivity Level value for csfBGA 285 Balls from 3 to 5. |

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| | |
|---|---|
| | • Added Moisture Sensitivity Level values for TQFP (Thickness: 1.4 mm) packages. |

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### Revision 3.6, December 2016

| Section | Change Summary |
| --- | --- |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size. Added WLCSP 30-ball package type. |

### Revision 3.5, June 2015

| Section | Change Summary |
| --- | --- |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size.<br>• Added caBGA package type for iCE40 Ultra.<br>• Added QFN package type for iCE40 Ultra. |
| Technical Support Assistance | Updated Technical Support Assistance section. |

### Revision 3.4, October 2014

| Section | Change Summary |
| --- | --- |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size.<br>• Added ucFBGA packages for ECP5.<br>• Added csfBGA package type for ECP5. |

### Revision 3.3, October 2014

| Section | Change Summary |
| --- | --- |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size.<br>• Added caBGA packages for MachXO3L.<br>• Added csfBGA package type for MachXO3L.<br>• Added WLCSP packages for MachXO3L. |

### Revision 3.2, June 2014

| Section | Change Summary |
| --- | --- |
| Pb-Free/Halogen-Free (RoHS-Compliant) Products | Updated Pb-Free/Halogen-Free (RoHS-Compliant) Products section. Added packages. |
| Peak Reflow Temperature (TP) by Package Size | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size. Added WLCSP package types for iCE40 Ultra. |

### Revision 3.1, May 2014

| Section | Change Summary |
| --- | --- |
| Pb-Free/Halogen-Free (RoHS-Compliant) Products | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size. Added QFNS package type for MachXO2 and iCE40 LP384. |
| Reflow Profile for SMT Packages | Updated Table 9.1 Peak Reflow Temperature (TP). Updated the $t_P$ parameter for Pb-Free and Halogen-Free packages based on J-STD-020D.1 standard. |
| Technical Support Assistance | Updated Technical Support Assistance information. |

### Revision 3.0, August 2013

| Section | Change Summary |
| --- | --- |
| Pb-Free/Halogen-Free (RoHS-Compliant) Products | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size. |

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### Revision 2.9, February 2013

| Section | Change Summary |
|---|---|
| Pb-Free/Halogen-Free (RoHS-Compliant) Products | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size. |

### Revision 2.8, August 2012

| Section | Change Summary |
|---|---|
| All | Updated document to support iCE40 mobile FPGA packaging:<br>• 36, 49, 81, 121 and 225-ball ucBGA<br>• 81 and 121-ball csBGA<br>• 36 and 84-ball QFNS<br>• 100-pin TQFP (1.0 mm thickness) |

### Revision 2.7, April 2012

| Section | Change Summary |
|---|---|
| All | Updated document to include the 328-ball csBGA package. |

### Revision 2.6, February 2012

| Section | Change Summary |
|---|---|
| All | Updated document with new corporate logo. |

### Revision 2.5, June 2011

| Section | Change Summary |
|---|---|
| All | Updated document to include 25 WLCSP package. |

### Revision 2.4, November 2010

| Section | Change Summary |
|---|---|
| All | Updated for Halogen-free package support. |

### Revision 2.3, June 2009

| Section | Change Summary |
|---|---|
| Pb-Free/Halogen-Free (RoHS-Compliant) Products | • Updated QFN information in Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size, SnPb Packages table.<br>• Updated QFN information in Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size, Pb-Free Packages table. |

### Revision 2.2, April 2008

| Section | Change Summary |
|---|---|
| Pb-Free/Halogen-Free (RoHS-Compliant) Products | Updated Table 8.2 Peak Reflow Temperature (TP) by Package Type and Size. |

### Previous Lattice releases

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