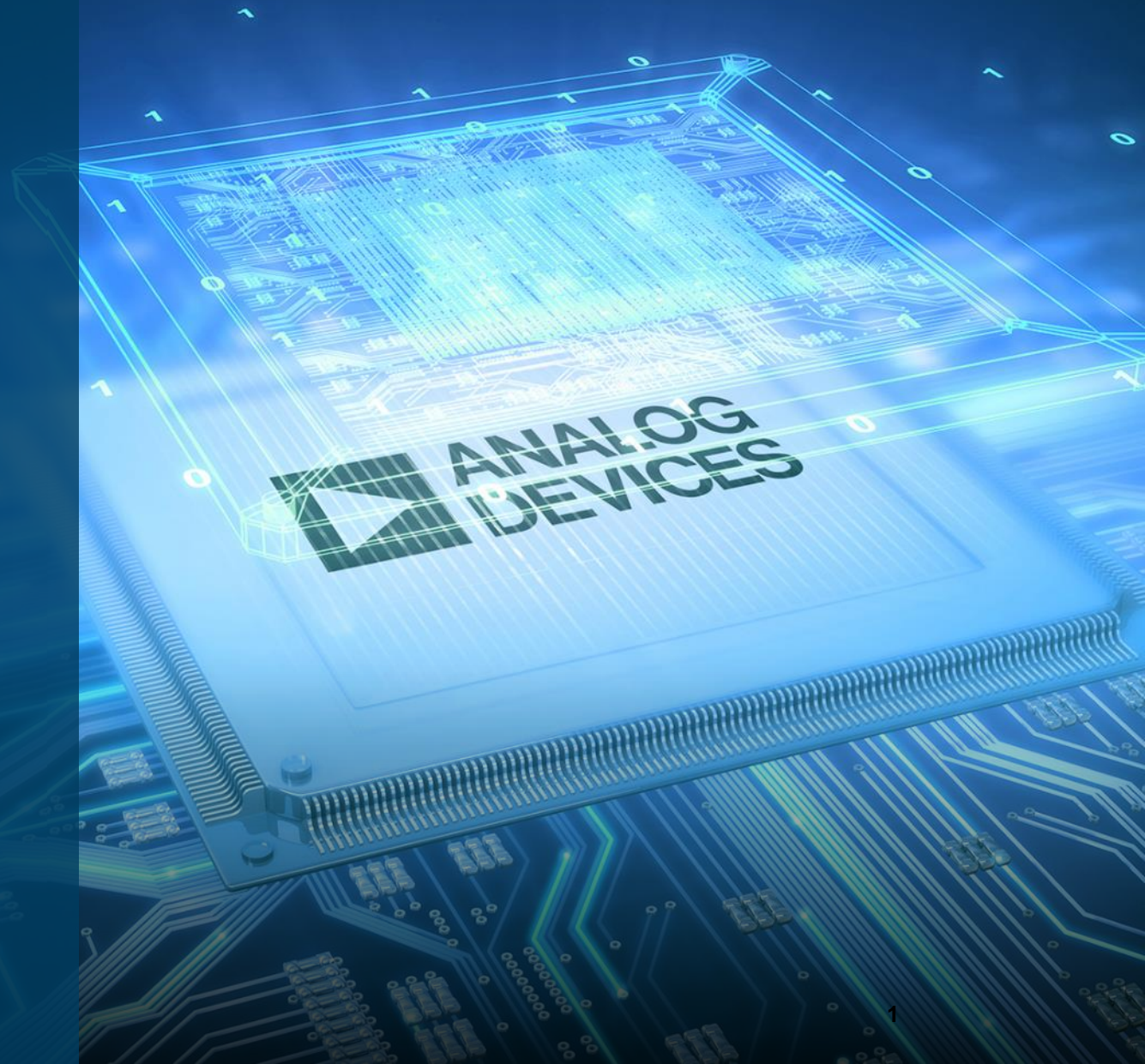


Assembly Considerations for Analog Devices Inc., μ Module™ BGA Packages

APRIL 2019



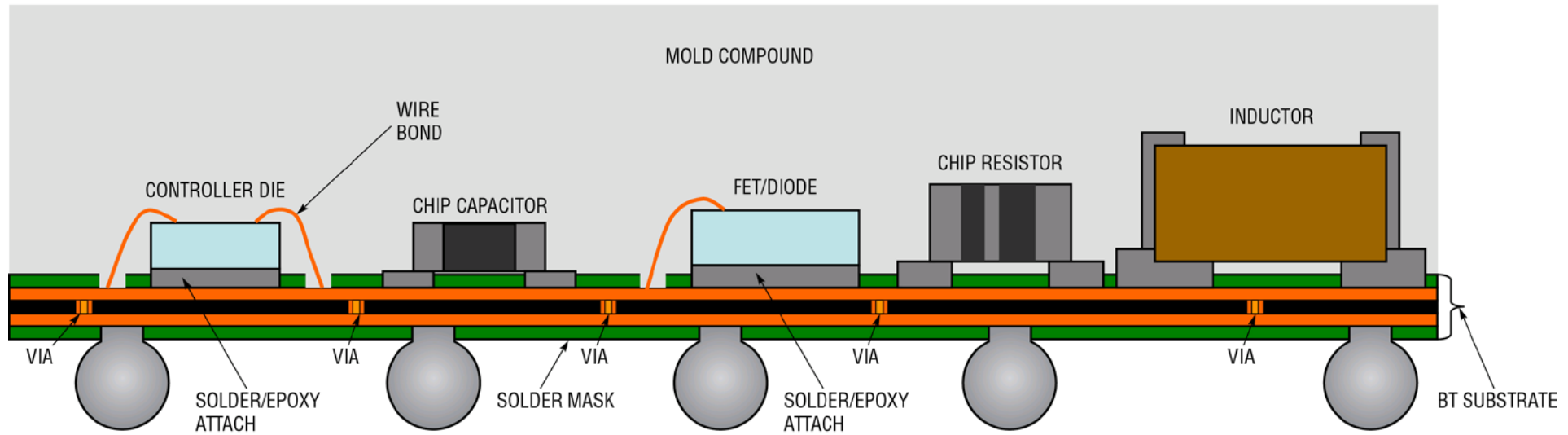
Outline

- ▶ Package Construction
- ▶ PCB Design Guidelines
- ▶ Moisture Sensitivity Considerations
- ▶ Board Assembly Process
 - Screen Print
 - Stencil Design
 - Solder Paste, Key Process Parameter
 - Reflow Profile
 - Removal and Rework
- ▶ Component on Package (CoP) Handling
- ▶ Drop Test, Static Loading & Vibration Test
- ▶ Attachments
- ▶ FAQ's

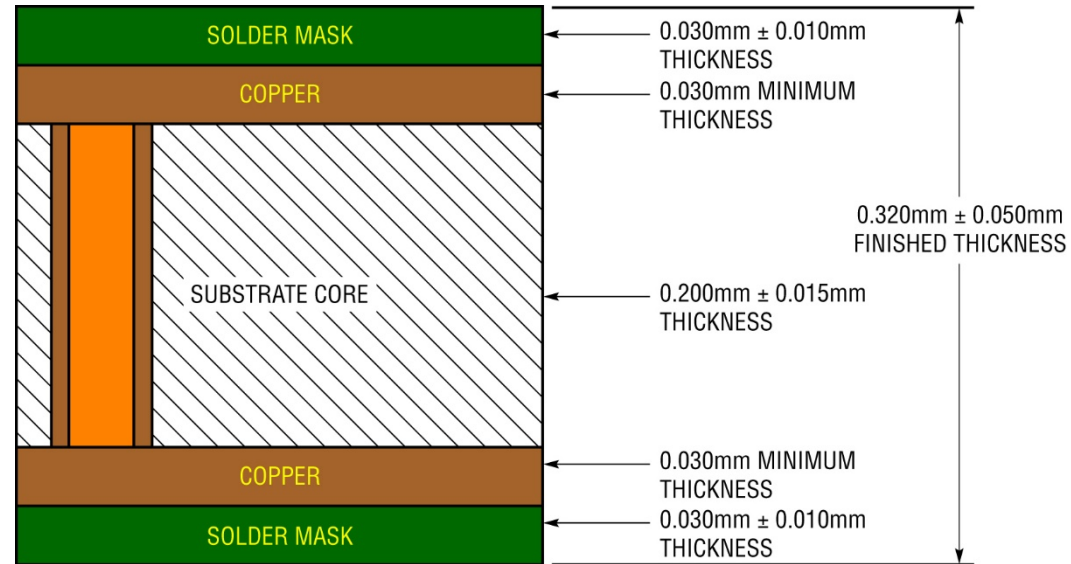
Package Construction

μModule™ BGA Package Construction

(Not To Scale)



Substrate Construction (Example, 2L substrate)

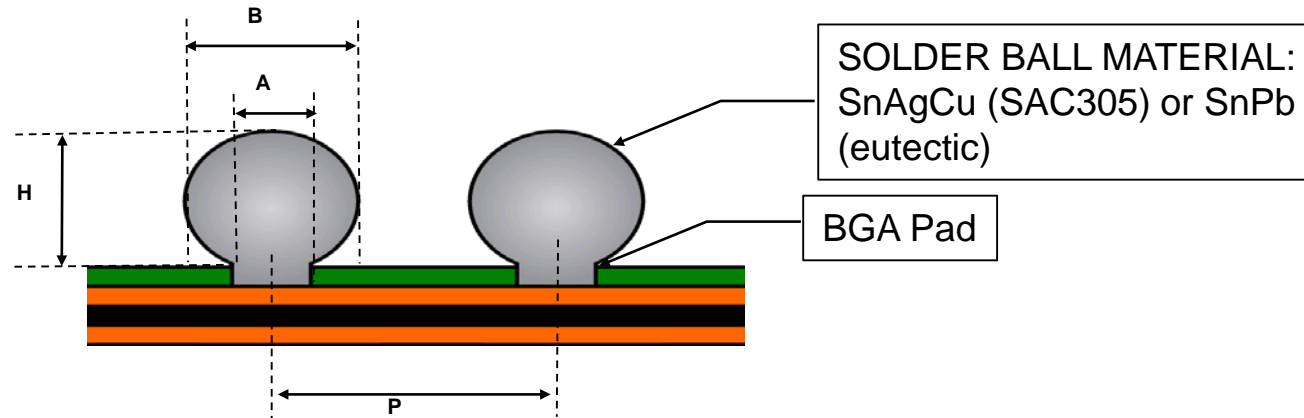


All dimensions in mm

SOLDER MASK = Taiyo ink PSR 4000

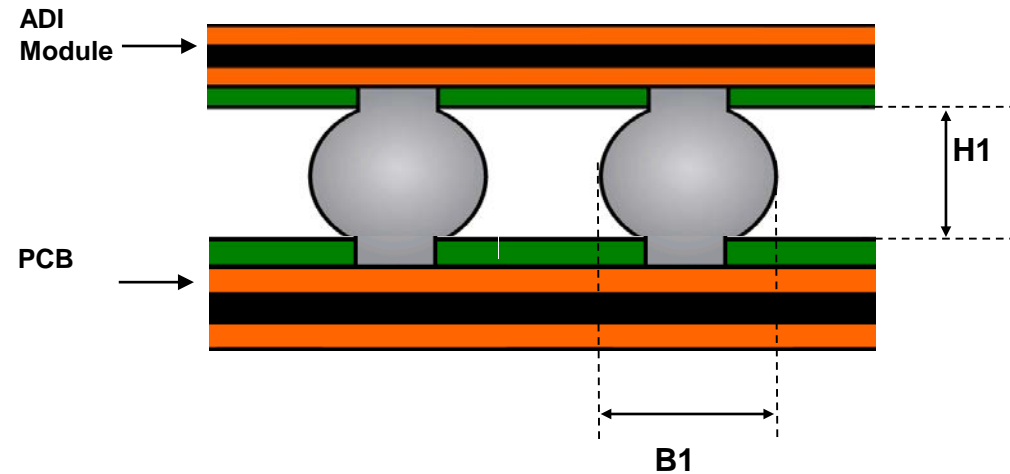
CORE = Mitsubishi Gas Chemical CCL-HL-832

Pad and Ball Geometry



| Package Solder Ball and Pad Dimensions (mm) | | | |
|--|------------------|---------------------------|------------------------|
| BGA Pad Pitch (P) | Pad Opening, (A) | Solder Ball Diameter, (B) | Solder Ball Height (H) |
| 0.8 | 0.40 | 0.50 | 0.40 |
| 1.00 | 0.50 | 0.60 | 0.50 |
| 1.27 | 0.63 | 0.76 | 0.60 |

Ball Geometry (Post SMT)



| Ball Geometry (Post SMT) (mm) | | | | |
|----------------------------------|--------------------------|-----------------------------|----------------------------------|---|
| BGA Pad Pitch | Raw Solder Ball Diameter | Pad Size on Package and PCB | Final Solder Ball Diameter, (B1) | Final Solder Ball Height after SMT (H1) |
| 0.8 | 0.50 | 0.40 | 0.45 – 0.55 | 0.35 – 0.45 |
| 1.00 | 0.60 | 0.60 | 0.55 – 0.65 | 0.40 – 0.60 |
| 1.27 | 0.76 | 0.63 | 0.60– 0.90 | 0.50 – 0.70 |

PCB Design Guidelines

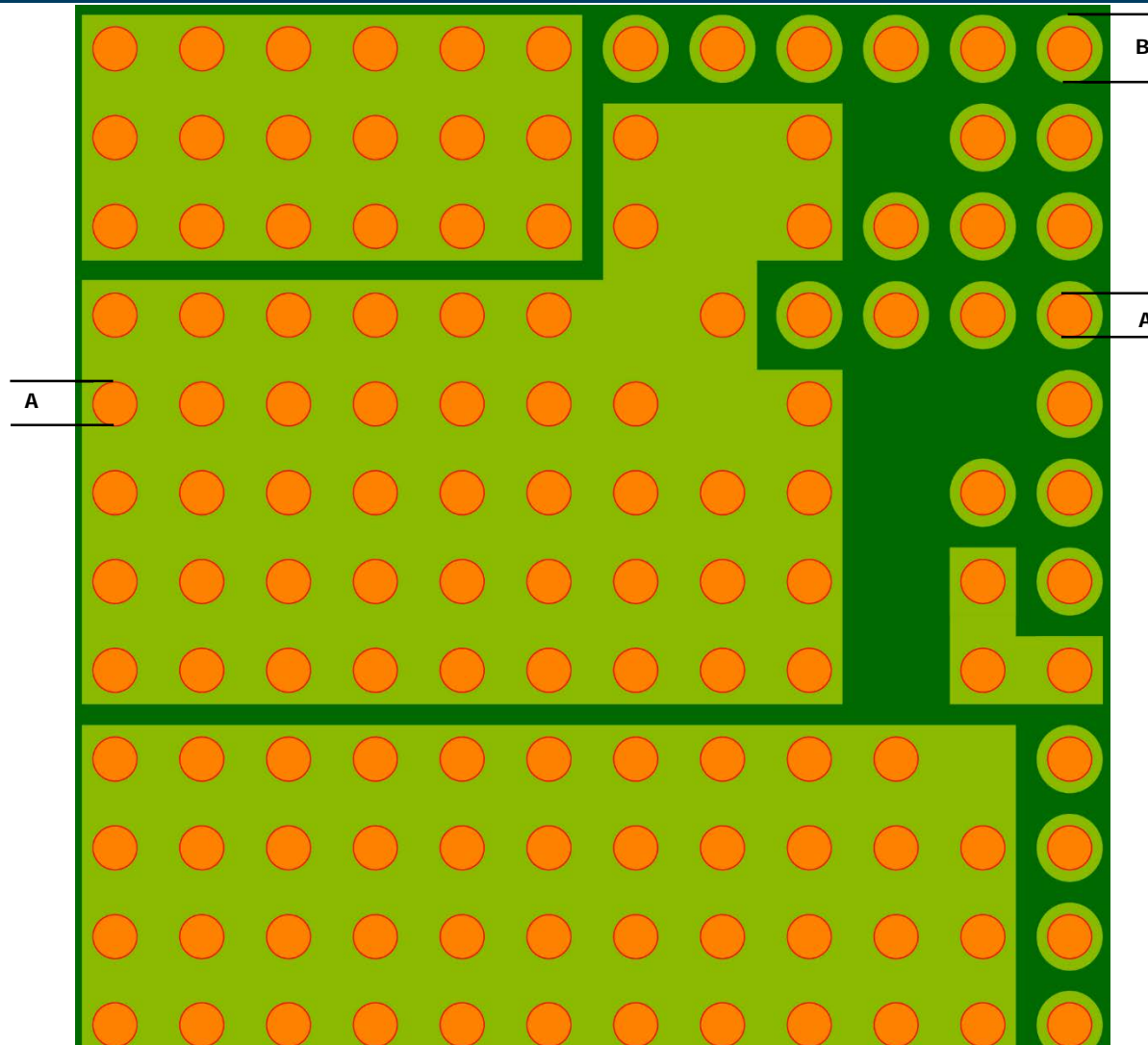
PCB Design Guidelines

- ▶ μ Module BGA
 - All pads are solder mask defined (SMD)
- ▶ SMD vs NSMD pads on PCB
 - NSMD pads preferred for signal pins
 - SMD OK to use
- ▶ PCB Pad Layout (SMD Pads)
 - Recommend using planes with SMD pads (same size as Package Pad opening)
 - Vias between Pads (on the planes) on top layer
- ▶ Non solder mask defined (NSMD) pads
 - Recommended Pad Layout
- ▶ Pad finish on PCB
 - OSP, ENIG recommended
 - Immersion Sn
 - Check for any dendritic growth with moisture
 - Immersion Ag
 - Oxidation issues

Solder Mark Defined Pads

Recommended PCB Pad Layout

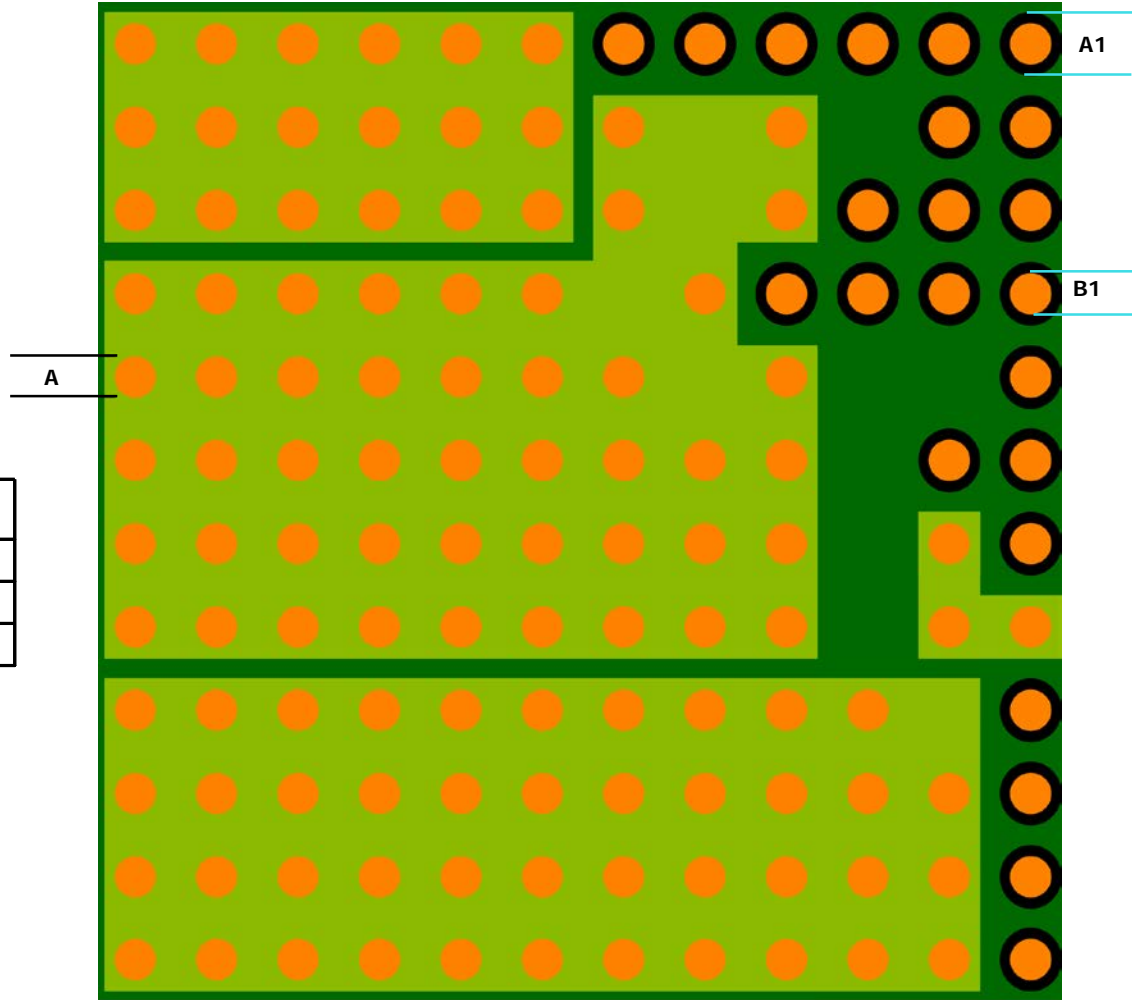
| Pitch (mm) | A (mm) | B (mm) |
|---------------|-----------|-----------|
| 0.8 | 0.40 | 0.50 |
| 1.00 | 0.50 | 0.60 |
| 1.27 | 0.63 | 0.73 |



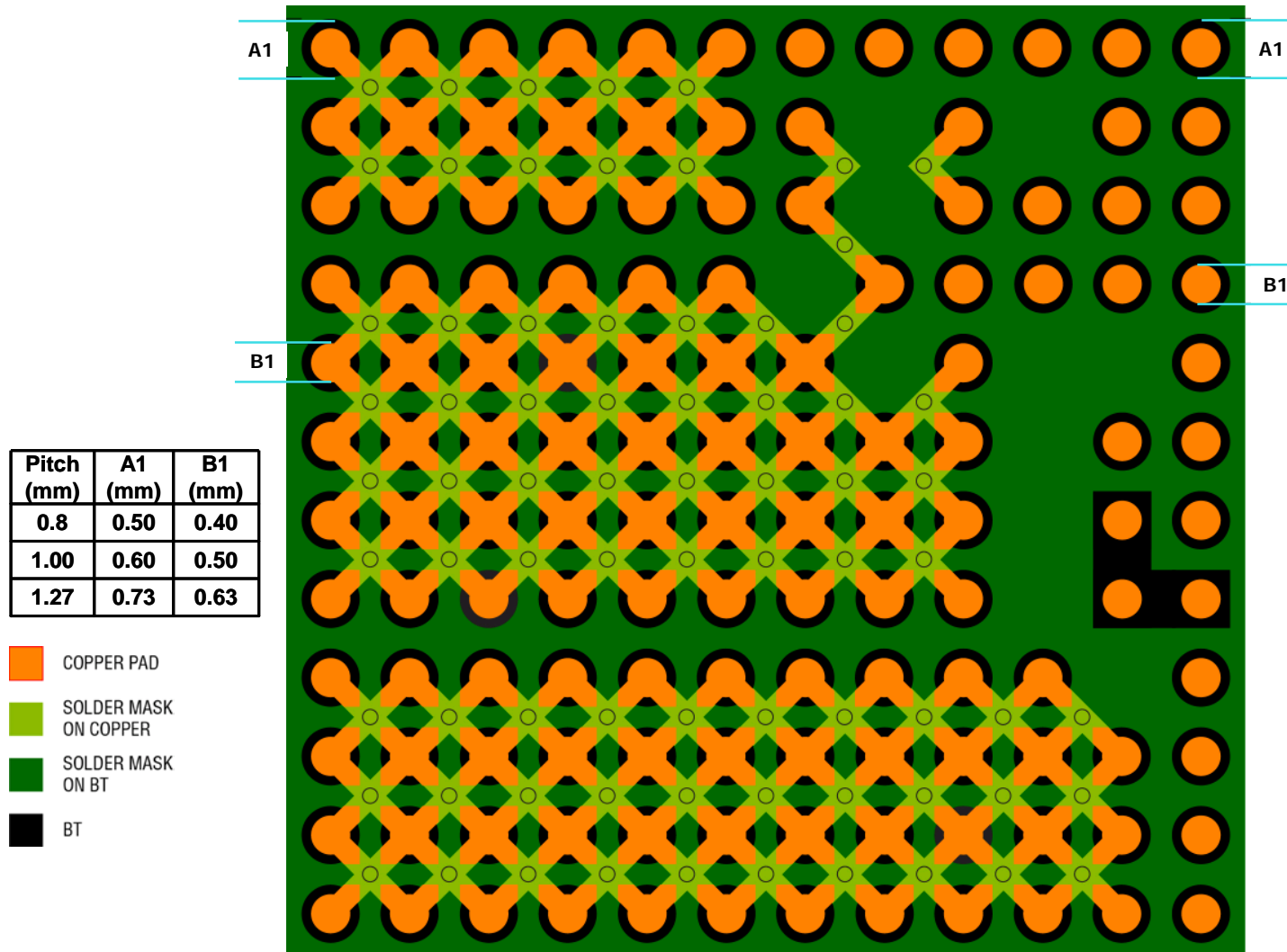
Mixed Pads (SMD and NSMD)

| Pitch (mm) | A (mm) | A1 (mm) | B1 (mm) |
|---------------|-----------|------------|------------|
| 0.8 | 0.40 | 0.50 | 0.40 |
| 1.00 | 0.50 | 0.60 | 0.50 |
| 1.27 | 0.63 | 0.73 | 0.63 |

 COPPER PAD
 SOLDER MASK ON COPPER
 SOLDER MASK ON BT
 BT

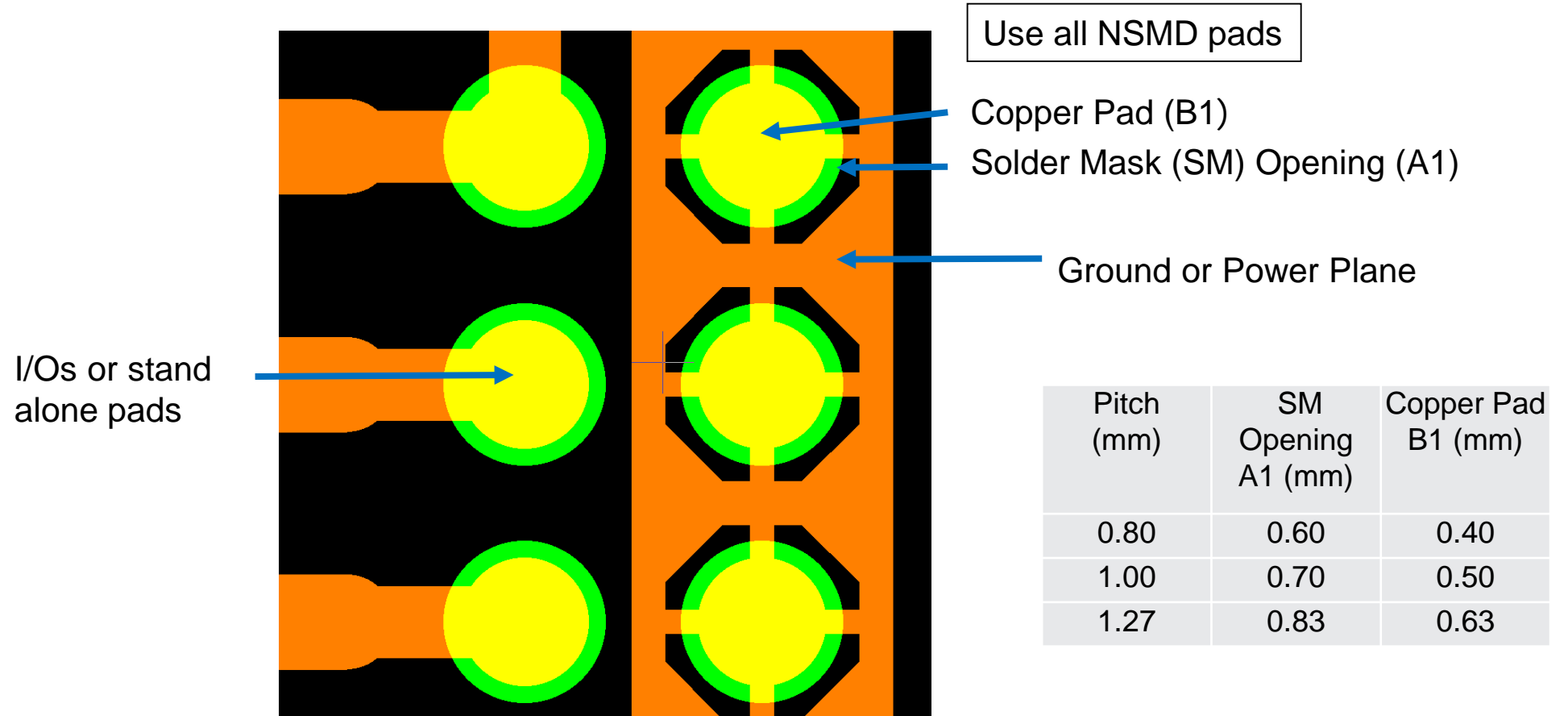


Thermal Relief: NSMD



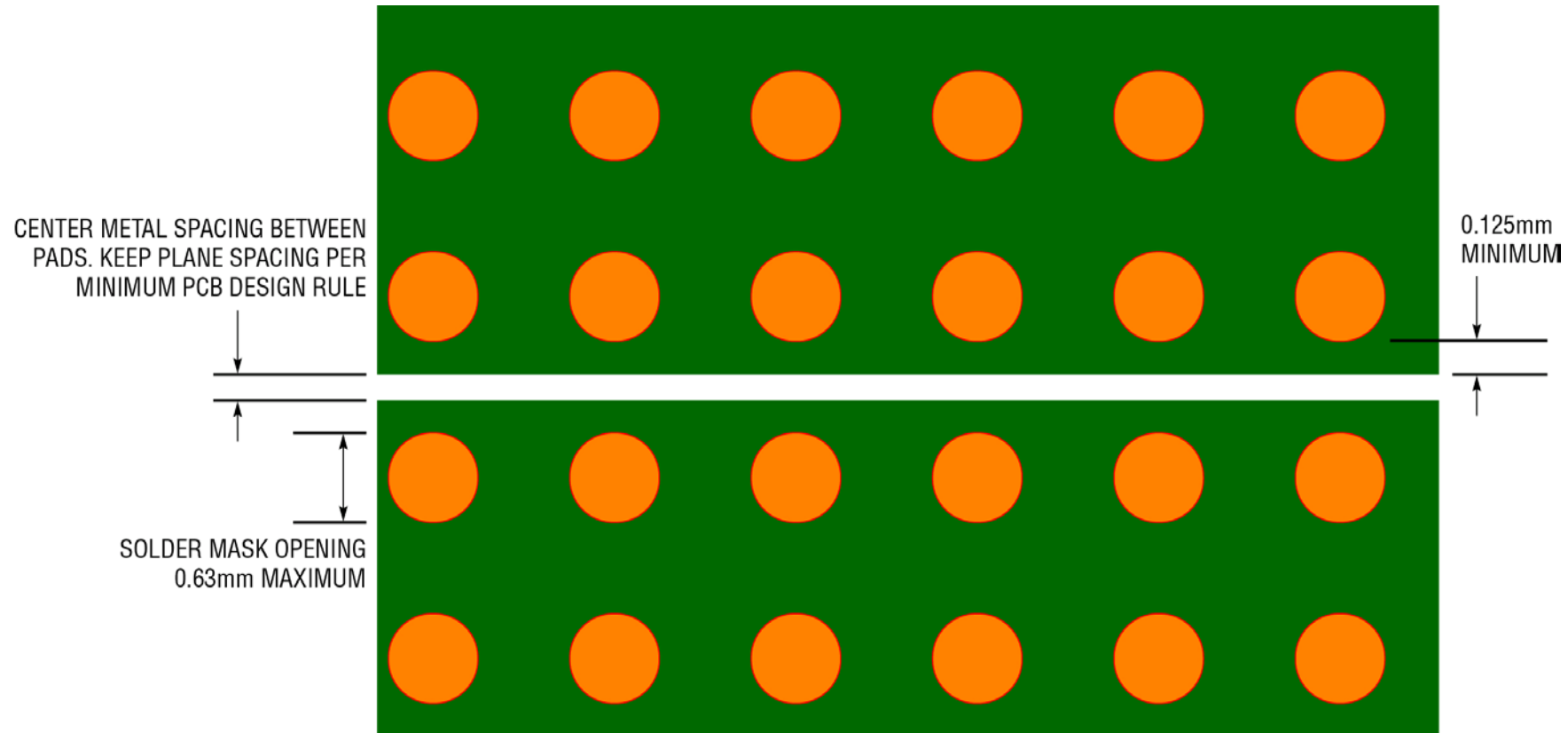
Isolator Products Pad Design Guideline

LTM28XX, LTM9100



PCB Plane Separation Guideline

Maximum solder mask opening for plane separation needs to be controlled; Stencil opening in this area can be reduced to 0.6 to ensure no bridging;
Critical area – under Inductor and plane separation



Moisture Sensitivity Considerations

Moisture Sensitivity, Pack, Ship & Bake

- ▶ μ Module products meet MSL level 3 or level 4 of the JEDEC Specification J-STD-020 (check the label on the shipping box for the correct MSL level (for the specific product))
- ▶ ADI ships all μ Module devices in trays (or samples in sealed tubes) with desiccant and moisture level indicator
- ▶ Check the packing integrity (may need to check the source of shipment for repack procedures if
 - Parts received in partial trays (other than from ADI)
 - Tape & Reel (No parts in Tape & Reel are shipped from ADI; If the authorized distributor shipped in T&R, need to use up the reel within the MSL floor life. If floor life is exceeded, parts need to be transferred to trays and baked at 125 C for 48 hours)
 - Tubes (other than from ADI)
- ▶ If any of the above packing methods are encountered, moisture indicator shows pink color, or punctured seal of the bag is observed, bake the packages per the following conditions:
 - 125°C for 48 hours
- ▶ Follow J-STD-033 “Handling, Packing, Shipping, and Use of Moisture/Reflow Sensitive Surface Mount Devices”

Board Assembly Process

Stencil Design Recommendation

- ▶ Stainless steel laser cut stencils recommended
- ▶ Recommended slightly smaller stencil aperture than the pad opening (especially for SMD pads)
 - To prevent paste from contacting solder mask

| Recommended Stencil Dimensions | | | |
|--------------------------------|---------------------|-------------------------|-----------------------------|
| BGA Pad Pitch (mm) | Pad Opening (mm) | Stencil Opening (mm) | Stencil Thickness (mils) |
| 0.80 | 0.40 | 0.38 | 4 - 5 |
| 1.00 | 0.50 | 0.48 | 4 - 5 |
| 1.27 | 0.63 | 0.60 | 4 - 5 |

Screen Print

- ▶ Solder Paste
 - Low voiding paste
 - Type III or IV
 - Paste types used at Analog Devices Inc. or by our customers include, but are not limited to,
 - PB free (SAC305) No Clean Kester 907, AIM NC254, Indium SAC – 5.1AT, 5.8LS, Alpha OM-325, OM-338T
 - PB free (SAC305) Water Soluble Kester 520A, AIM SAC-WS353, Indium 3.2
- ▶ Key Process Parameters
 - Paste Rheology, Blade pressure, Paste floor life
- ▶ Check print definition, cleaning frequency
 - Stencil clogging can show as partial solder joints, not well defined joints

Reflow Profiles

- ▶ Both Air and N2 systems are OK (depends on solder paste)
- ▶ Recommend using a 9 zone or greater oven
- ▶ Profile with all components (fully populated board) and thermocouples under the μ Module devices.
- ▶ Check that the solder paste vendor recommended profile conforms to ADI recommendations
 - If the ADI recommended profile cannot be met, adhere to the paste vendor profile except peak reflow temperature; Peak reflow temperatures must not exceed the temperatures listed in Table A & Table B

Table A: Pb- Free Process - Package Peak Reflow Temperature

| PACKAGE THICKNESS | VOLUME | VOLUME | VOLUME |
|-------------------|-----------------------|--|------------------------|
| | < 350 mm ³ | 350 mm ³ - 2000 mm ³ | ≥ 2000 mm ³ |
| < 1.6mm | 260 + 0 °C | 260 + 0 °C | 260 + 0 °C |
| 1.6mm - 2.5mm | 260 + 0 °C | 250 + 0 °C | 245 + 0 °C |
| ≥ 2.5mm | 250 + 0 °C | 245 + 0 °C | 245 + 0 °C |

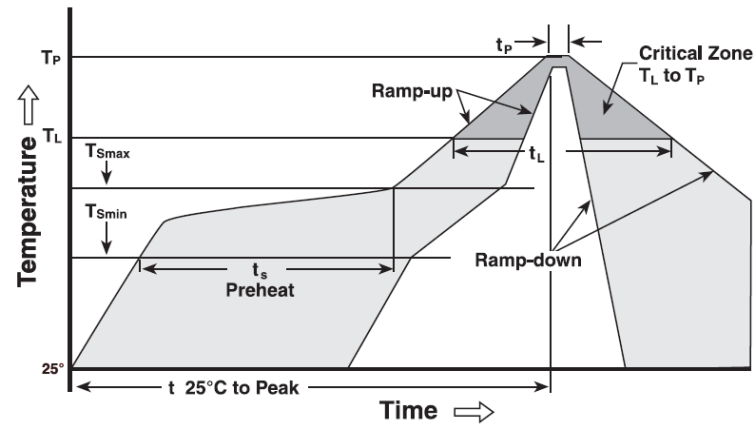
Table B: SnPb Eutectic Process - Package Peak Reflow Temperature

| PACKAGE THICKNESS | VOLUME | VOLUME |
|-------------------|-----------------------|-----------------------|
| | < 350 mm ³ | ≥ 350 mm ³ |
| < 2.5mm | 240 + 0/-5 °C | 225+ 0/-5 °C |
| ≥ 2.5mm | 225 + 0/-5 °C | 225 + 0/-5 °C |

2 sided reflow is not recommended for these devices (see Attachment I)

- LTM2881, LTM2882, LTM2883, LTM2884, LTM2885, LTM2886, LTM2887, LTM2889, LTM2894, LTM9100
- All Component on Package (CoP) LTM4636, LTM4678, LTM4626, LTM4638, LTM4680, LTM4700, LTM4664

Reflow Profiles



| Profile Feature | | Lead-Free Solder | Leaded Solder |
|---|--|------------------|------------------|
| Pre-heat | Min Soak Temperature Min (T_{smmin}) | 150°C | 100°C |
| | Max Soak Temperature (T_{smmax}) | 200°C | 150°C |
| | Soak Time (t_s) | 60-120 seconds | 60-120 seconds |
| Reflow | Liquidus Temperature (T_L) | 217°C | 183°C |
| | Time above Liquidus (t_L) | 30-90 seconds | 30-90 seconds |
| Peak Package Body Temperature (T_P) | | See Table A | See Table B |
| Time within 5°C of peak temp(T_P) | | 30 seconds max | 30 seconds max |
| Average Ramp up Rate (T_{smmax} to T_P) | | 2.5°C/second max | 2.5°C/second max |
| Ramp Down Rate | | 2.5°C/second max | 2.5°C/second max |
| Time 25°C of peak temp | | 8 minutes max. | 8 minutes max. |
| Do not exceed | | See Table A | See Table B |

Solder Joint Voiding

- ▶ ADI/IPC recommends using a 25% maximum void criteria for solder joints
- ▶ If the recommended ADI or paste vendor profile results in >25% voiding, then use a soak profile during reflow (Profile with Thermocouple underneath the BGA)
 - For Pb free paste, ramp to 180°C to 200°C and stay at 200°C to 210°C for 90 to 110 sec
 - For Sn/Pb paste ramp to 150°C and stay for 90 to 110 sec
 - If the above soak times are outside the range of the paste vendor recommended profile, keep the soak time to the maximum allowed per the paste vendor

Rework

Component Removal (μModule™ Device)

- ▶ Determine the failure mode from the board and at what operation the defect(s) occurred
 - After assembly
 - Is it opens or shorts?
 - Opens : Check solder joint quality, partial joint, no joint, cold solder
 - Shorts : X ray to check (Pad design, stencil design)
 - Electrical test
 - No output : Check output caps next to the module
 - Shorting
 - Need X-ray to verify short location internal or external to package
 - X-ray checks need to be done on the board
- ▶ Remove the component from the board within 168 hrs (MSL3 products) or 72 hrs (MSL4 products) of the moisture barrier bag opening prior to assembly or after baking the PC board assembly for 24 hours 125°C; if multiple LTM's are on the board, it is recommended to bake the PC board assembly for 48 hours to make sure other LTM's are not affected during the removal process.
 - If this step is not followed, there is a possibility of delamination of the mold compound from the substrate (solder mask)
 - If the part is heated above 245 deg C, the internal solder in the module will melt and may spread through the delaminated areas
 - If the part was baked properly, the solder does not spread and is held within the pad

Rework

Component Removal (μ Module™ Device)

- ▶ Use a BGA rework station capable of profiling the top and bottom of Module
 - Handheld heat guns or IR-only rework stations should not be used
 - Use appropriate heat shielding of sensitive components in proximity to the μ Module
 - The profile is done with a thermocouple on top of the part and another at the bottom of the part (close to the solder joints)
 - Maximum temperature for top of package = 245°C
 - Maximum bottom temperature (at solder joint) = 230°C to 245°C
 - Keep the bottom temperature as low as possible and increased time to melt the solder for package removal
 - Note: maximum top/bottom temperatures for Sn/Pb BGA can be set to 220°C
 - Ensure that the solder has reached above the liquidus temperature
 - If the solder is not completely molten, the PCB pads may be lifted during removal

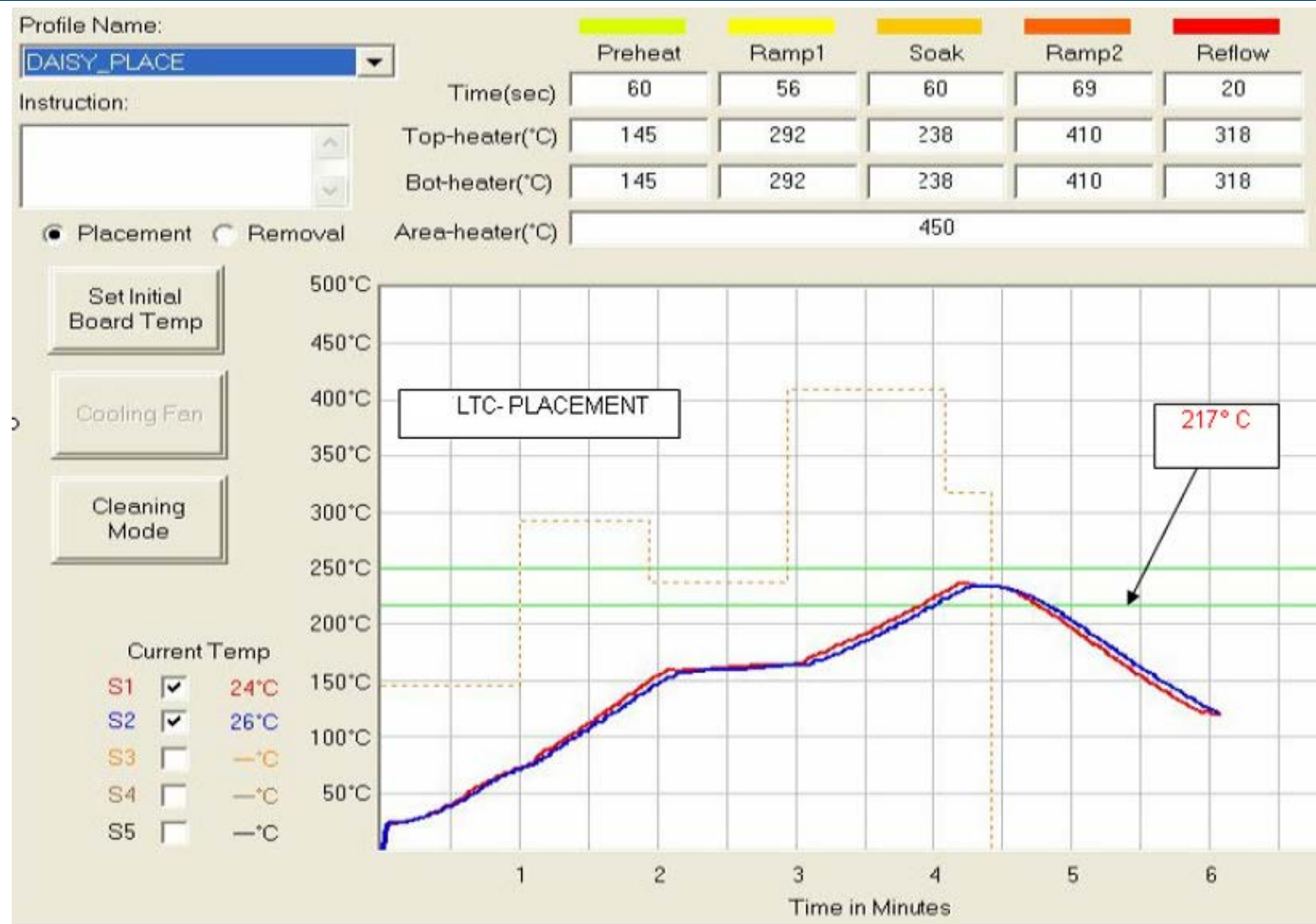
Rework

Component Attachment (μModule™ Device)

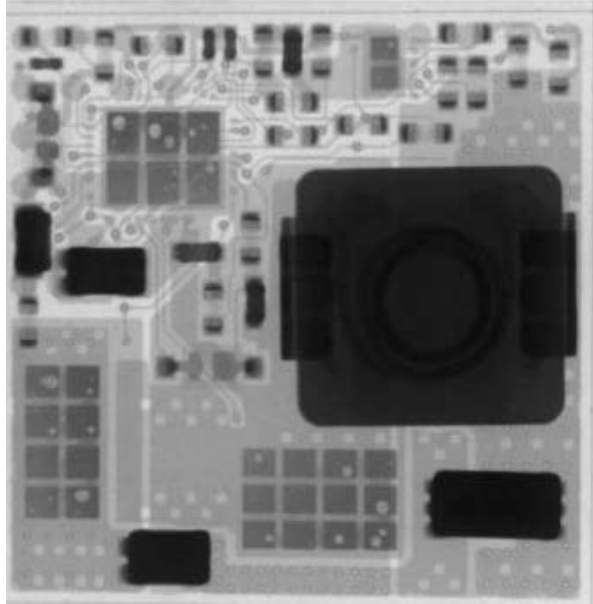
- ▶ Cleaning and prep of PCB lands
 - Solder wick or solder iron can be used
 - Ensure PCB pads are not damaged during the cleaning process (excess heat or excess mechanical scraping can damage the pads)
- ▶ Screening of solder paste
 - Paste printing can be done on the component instead of PCB (no clearance issues)
 - Use a micro-stencil; Position the part onto the stencil frame; Hold the part in position
 - Print Type 3 or 4 no clean paste onto the new component on the pad side of the component
 - Ensure no clogging of the stencil; Clean stencil after each print
- ▶ Placement and reflow of new component
 - Removed component should not be reused
 - Use split vision system (align the printed pads on the component with the PCB land pattern)
 - Reflow profile to ensure adequate soaking time as well as time above liquidus
 - Profile with thermocouples on all modules which are connected in parallel
- ▶ Inspection of solder joints using X-ray

Rework Profile (PB free)...

- Removal and attachment

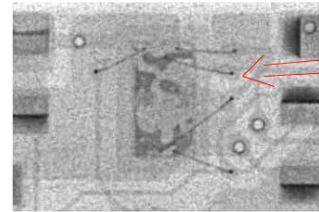


Example of good and bad μ Module Device after PCB assembly and rework

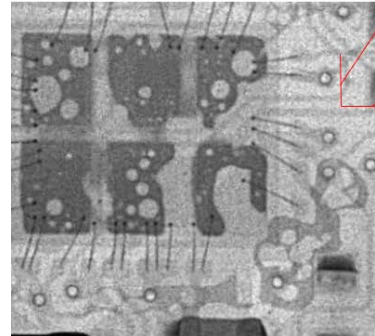


NO SHORTS

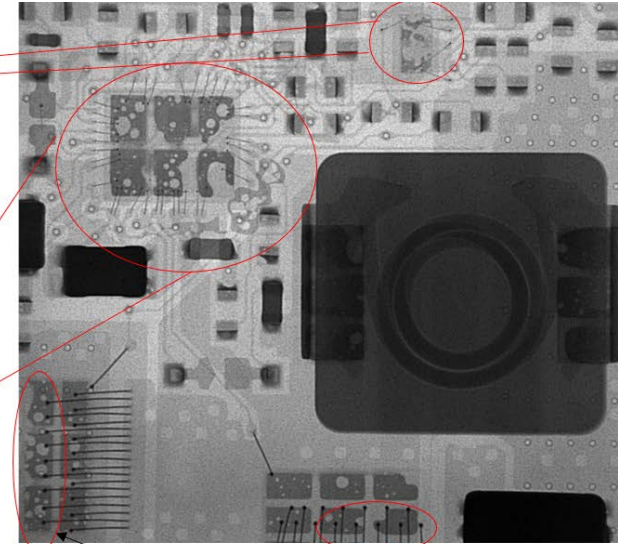
- Part meets Level 3 or Level 4 floor life
- Reflow peak temperature within the spec
- Part was baked and removed



Solder flow under U2 die



Solder flow under die



Partial solder flow under die: truncated window pane

SOLDER SHORTS INSIDE MODULE

- Part does not meet Level 3 or Level 4 floor life - **delamination**
- Reflow peak temperature out of spec – **solder melted & spread due to #1**
- Part was not baked prior to removal

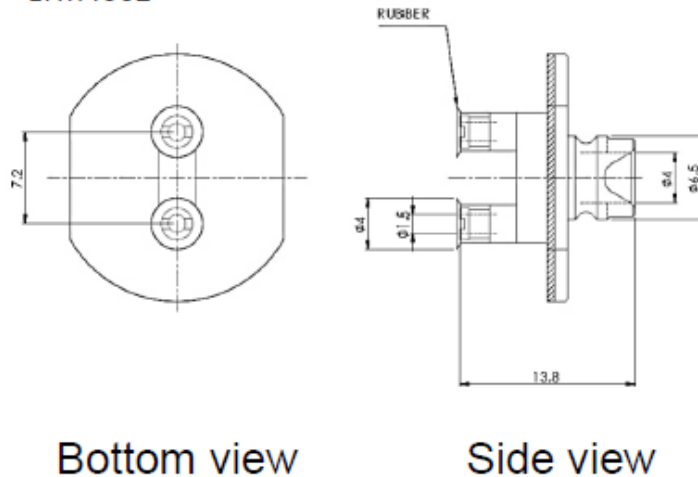
Component on Package (CoP) Handling

SMT Nozzle, Pick n Place for Packages with Component(s) on Top

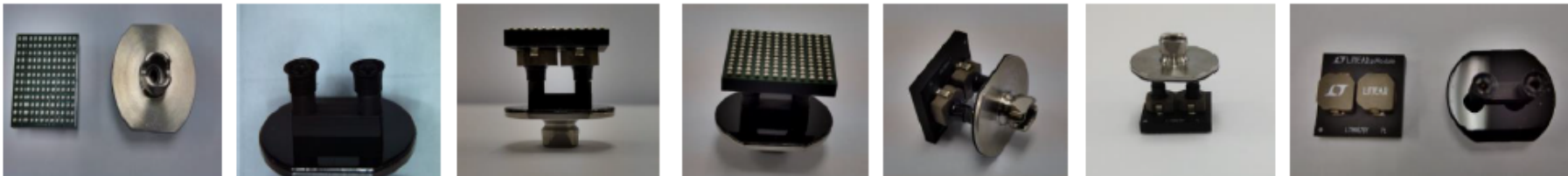
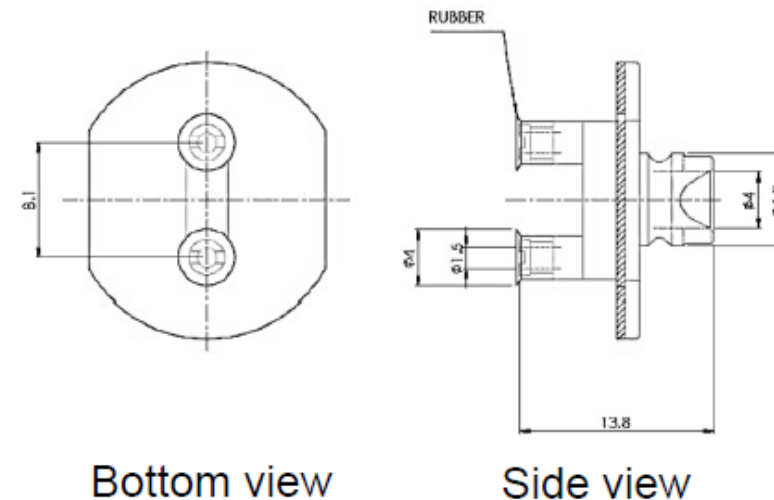
Type 1: Inductor Pick-up

Nozzle design layout.

Panasonic Dual Tip Vacuum Pad Nozzle (Pitching 7.2mm)
LTM4662



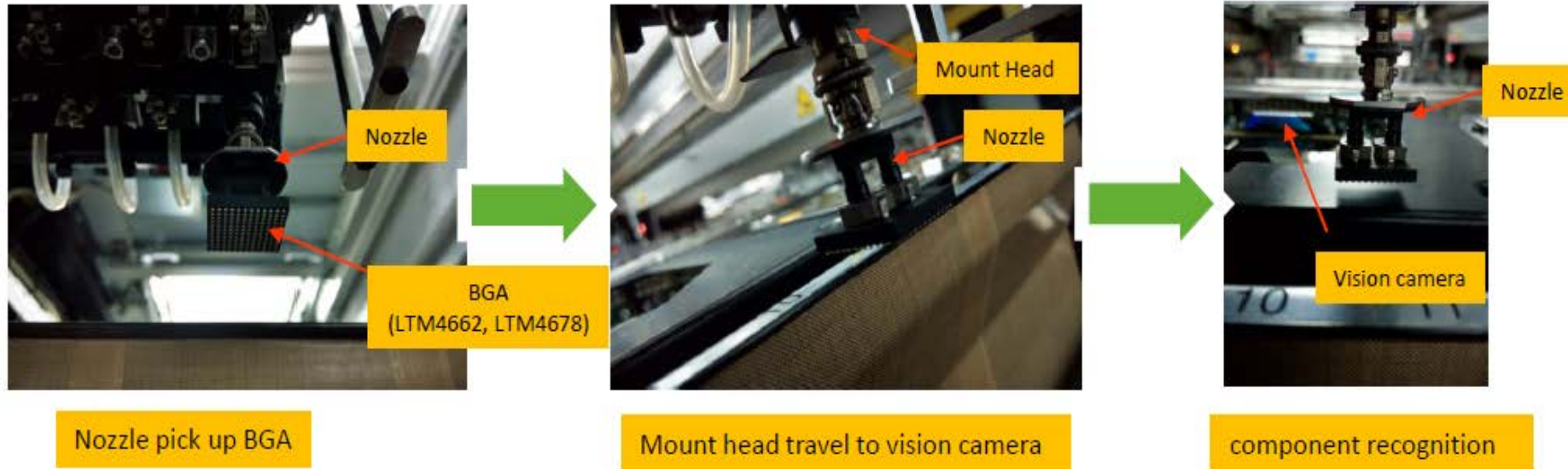
Panasonic Dual Tip Vacuum Pad Nozzle (Pitching 8.1mm)
LTM4678



SMT Nozzle, Pick n Place for Packages with Component(s) on Top

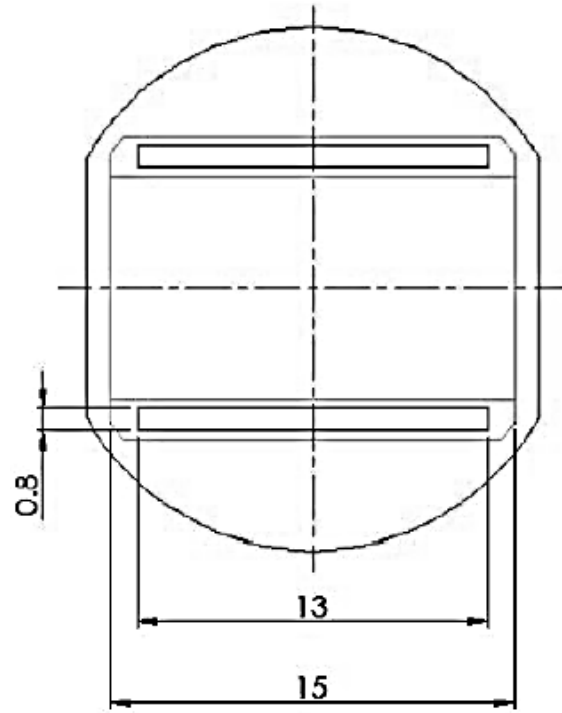
Type 1: Inductor Pick-up

Nozzle pick up component and vision flows sequence .

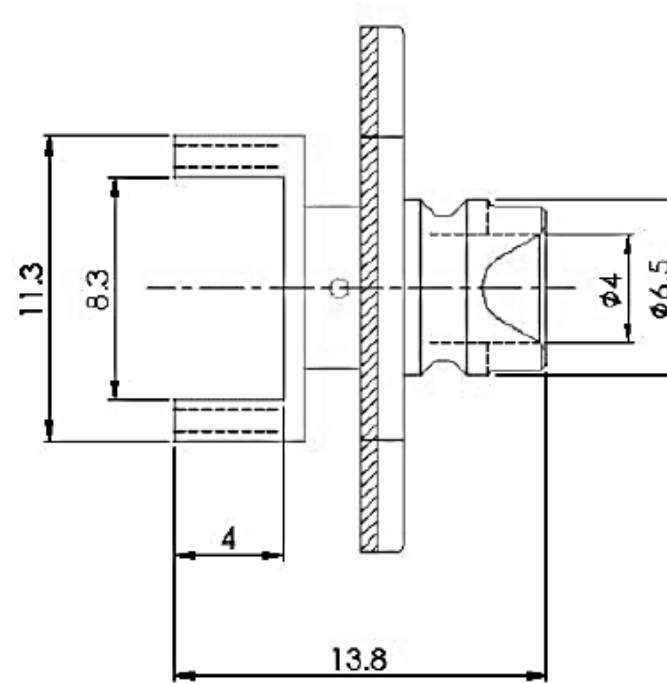


SMT Nozzle, Pick n Place for Packages with Component(s) on Top

Type 2: Package Body Pick-up



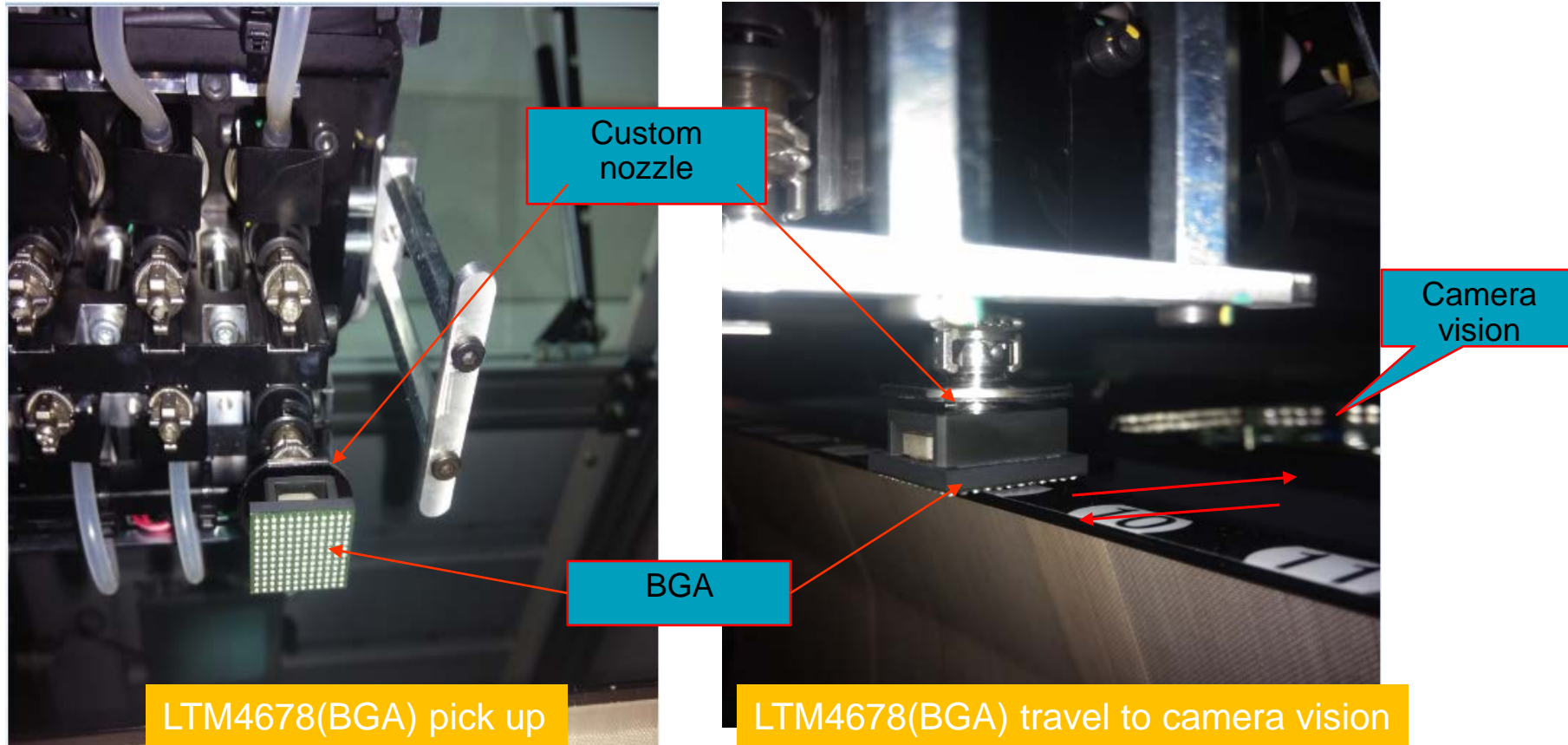
Bottom view



Side view

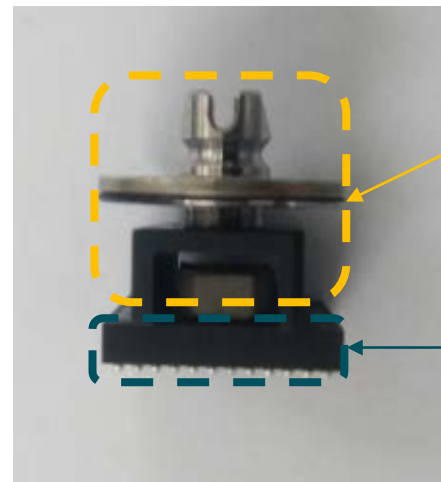
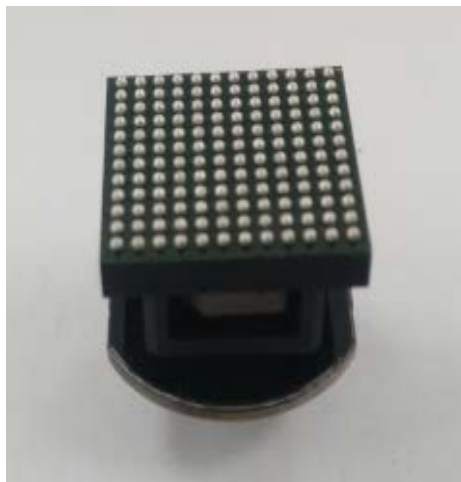
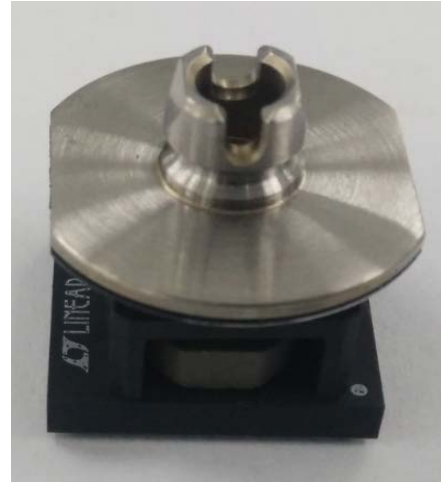
SMT Nozzle, Pick n Place for Packages with Component(s) on Top

Type 2: Package Body Pick-up



SMT Nozzle, Pick n Place for Packages with Component(s) on Top

Type 2: Package Body Pick-up



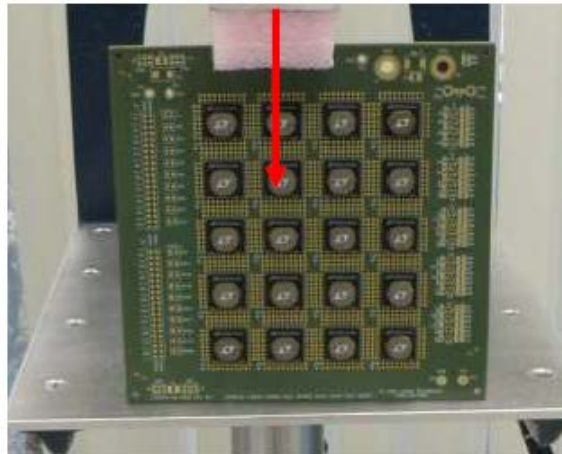
Custom
nozzle

BGA

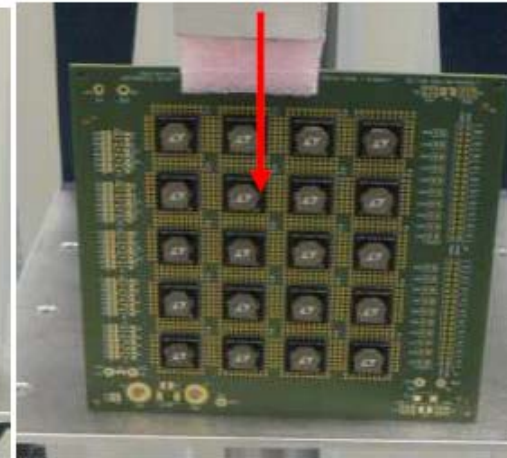
Drop Test, Static Loading & Vibration Test

Drop Test of CoP Packages: LTM4636

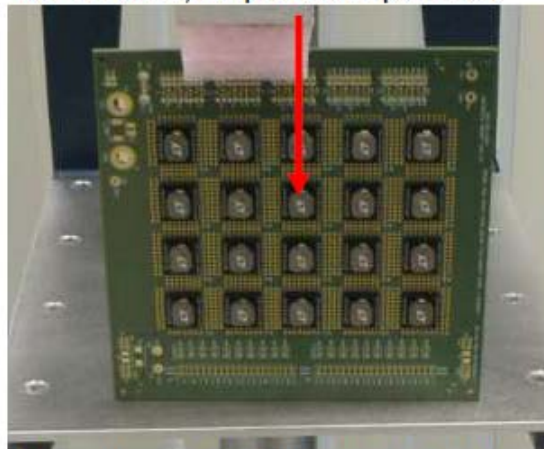
The orientations of the drops of the test samples were based on the positions as shown in the images below:



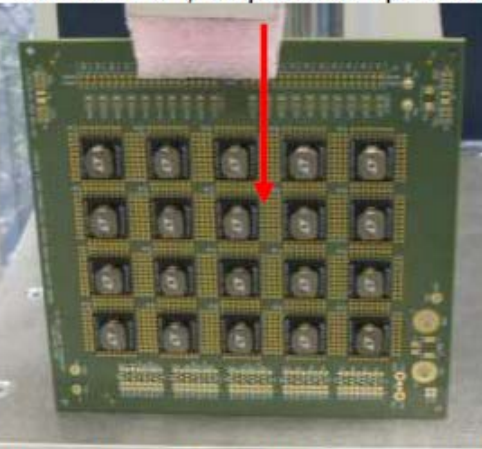
+X orientation, Drop direction per arrow



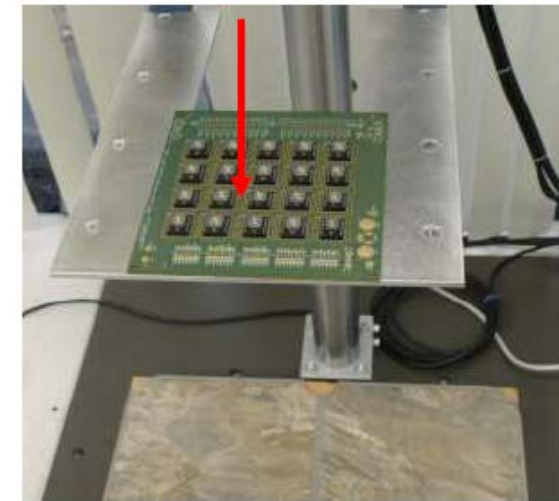
-X orientation, Drop direction per arrow



+Y orientation, Drop direction per arrow



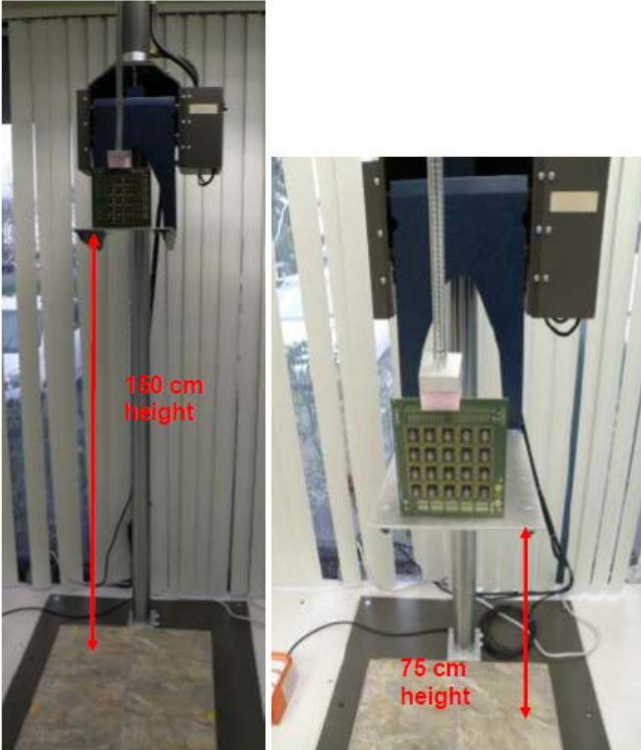
-Y orientation, Drop direction per arrow



-Z orientation,

Drop Test of CoP Packages: LTM4636

- The images below demonstrate the drop tester height



Test Results:

| Board #1, 75 Cm Drop Height | |
|-----------------------------|----------------------|
| Drop Direction | Post Drop Inspection |
| +X | Pass |
| -X | Pass |
| +Y | Pass |
| -Y | Pass |
| -Z | Pass |

| Board #2, 150 Cm Drop Height | |
|------------------------------|----------------------|
| Drop Direction | Post Drop Inspection |
| +X | Pass |
| -X | Pass |
| +Y | Pass |
| -Y | Pass |
| -Z | Pass |

- All parts passed visual inspection and continuity test

Static Loading Test of CoP Packages: -LTM4636/LTM4662/LTM4678

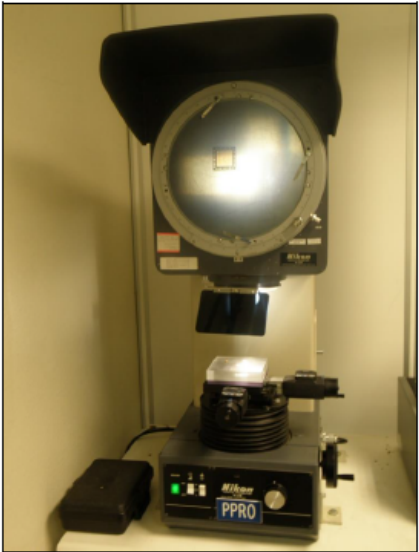
The equipment used for the test as listed in the table below:

| Process | Equipment |
|---------------------------------|-------------------------------------|
| Force Gauge | Mark-10 M7-200 Force Gauge |
| Test Stand | Mark-10 (Model TSA) |
| Timer | Extech Instruments Chronograph |
| Solder Balls Height Measurement | NIKON Profile Projector, Model V-12 |

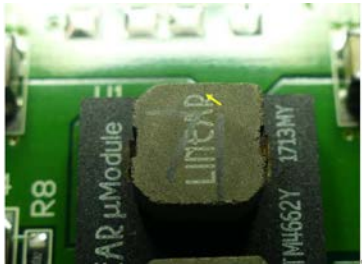
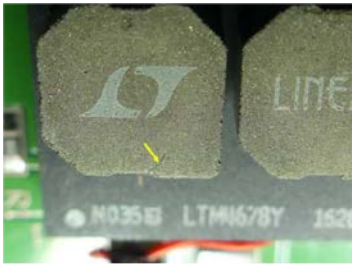
| | |
|------------------------------|---------------------------------|
| Force Tool Diameter | 20mm, Flat Metal Surface |
| Applied Force (Kg) | 1, 5, 10, 50, 75, 100, 125, 182 |
| Duration | 30 seconds |
| Number of cycles | 1X |
| Location of Applied Pressure | Center of Package |



Test Stand with Force Gauge



Nikon V-12



PART SHOWING PHYSICAL DAMAGE
TO INDUCTOR AT 182KG: ETEST PASS

MAX ALLOWABLE STATIC LOAD = 125KG
VISUAL INSPECTION: PASS
PASSED FUNCTIONAL TEST

Static Loading Test of CoP-TMSV Packages: -LTM4700

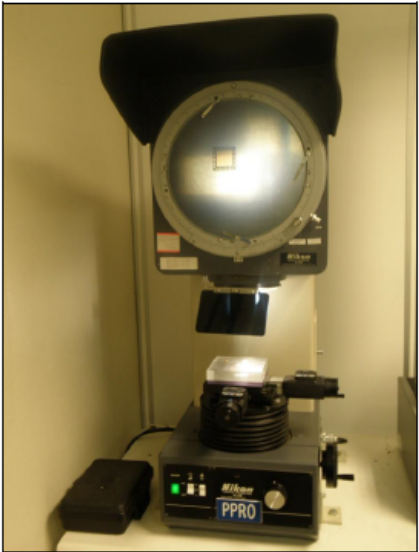
The equipment used for the test as listed in the table below:

| Process | Equipment |
|---------------------------------|-------------------------------------|
| Force Gauge | Mark-10 M7-200 Force Gauge |
| Test Stand | Mark-10 (Model TSA) |
| Timer | Exttech Instruments Chronograph |
| Solder Balls Height Measurement | NIKON Profile Projector, Model V-12 |

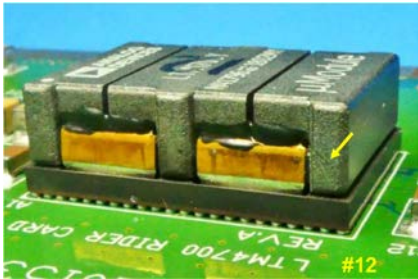
| | |
|------------------------------|--------------------------------|
| Force Tool Diameter | 1inch, Flat Metal Surface |
| Applied Force (Kg) | 1, 5, 10, 25, 50, 75, 100, 125 |
| Duration | 30 seconds |
| Number of cycles | 1X |
| Location of Applied Pressure | Center of Package |



Test Stand with Force Gauge



Nikon V-12



PART SHOWING PHYSICAL DAMAGE
TO INDUCTOR : ETEST PASS

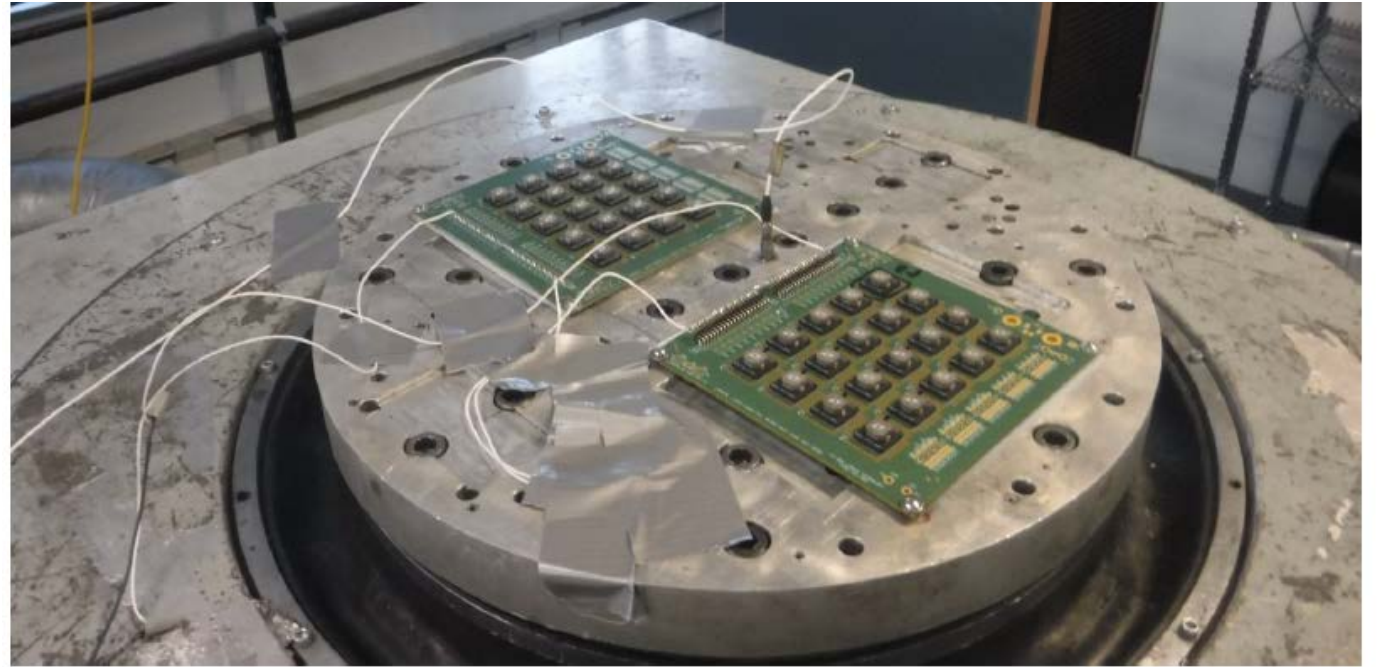
MAX ALLOWABLE STATIC LOAD = 125KG
VISUAL INSPECTION: MINOR CRACK
PASSED FUNCTIONAL TEST

Vibration Testing of CoP: LTM4636

Random Vibration Test: PASS

- MIL-STD-202G
- METHOD 214
- TEST CONDITION I, LETTER F
- Test Sample size: 2 PCB assembly
- PCB has 20 BGA devices (see image)
- SAC305 solder used for assembly
- Board thickness: 0.093" ENIG finish

Vibration Test Setup (x/y/z axis)



FAQ's

FAQ's

1. What is the stencil opening, thickness?
 - See Stencil design page
2. What type of paste to use?
 - Both no clean and water soluble are OK; Type III or IV
3. Can the PCB be cleaned effectively
 - Yes; Both inline and rotary aqueous systems have been used to clean effectively
4. How to inspect for the solder joints?
 - 5DX is an effective method to check for solder joint shorts; Endoscope used for inspection of peripheral joints
5. Can the μ Module product be used on both sides of the PCB?
 - Yes, provided the total exposure time(out of bag to 2nd reflow) is less than 168 hrs (for MSL3 products) or 72 hrs (for MSL4 products)
 - Exceptions: see slide on Reflow Profiles
6. Parts are shorting (Vin to Gnd or Vout to Gnd)
 - Check for solder joint shorts ((check the schematic with the pin configuration)
 - Check inside the module to see if any solder spreading has occurred

7. How to prevent shorting inside the module?

- Check the floor life of the parts (From opening of sealed bag to reflow); If over 168 hours (MSL3) or over 72 hours (MSL4) , parts need to be baked for 48 hrs at 125°C
- Was the bag not sealed or moisture indicator showing pink color? – Bake parts for 48 hrs at 125°C
- Was the reflow peak temperature greater than the peak temp for the module size (refer to the Table on slide titled “μModule MSL Rating”)? If yes, redo profile to bring the peak temperature below the spec level for the package
- Did the shorting happen after rework (removal)?
 - PCB must to be baked for 24 hours at 125°C
 - Heat gun should not be used for removal
 - If heat gun was used, temperature may be excessive
 - Profile the rework station and remove component

8. Can the removed module be reused?

- We do not recommend the reuse of the module after removal. Use a fresh part to replace

Attachments

Attachment I

Second Side Reflow

The suitability of BGA devices for second side (inverted) reflow during PCB manufacturing is primarily based on the components weight versus the surface tension created by the total number of device balls. During second side reflow the BGA balls are in tension and must support the devices weight plus additional acceleration factors such as equipment vibration, air flow, etc.

Due to these variables a safety factor must be applied to the ideal calculated weight.

The industry rule of thumb for maximum weight per ball in compression, with a 2X safety margin, averages to approximately 50mg/ball.

Analog Devices Inc. has verified this recommendation using computational fluid dynamic analysis and by actual reflow experiments. Analysis was also performed with the BGA devices in tension resulting in a 25mg/ball recommendation with a 2x safety margin.

Figure 1 shows the BGA ball height versus force exerted on the ball, for both compression and tension when the solder ball is in a liquid state. The ends of any particular curve represent the limiting case, balls collapse and most likely short to adjacent balls in compression or the device falls off the board in tension. Plots for both the ideal and a 2X safety margin case are displayed.

Analog Devices Inc. recommends that the suitability of all LGA and BGA μ Module devices be evaluated for second side reflow with consideration towards the PCB assembly equipment and process. If a devices data sheet specifically indicates it is not suitable for second side reflow, then it has been determined that either the number of balls is insufficient to support the devices weight in tension and compression or there is sufficient risk of assembly problems with the devices weight and manufacturing uncertainties. An assembly house may optionally choose to use epoxy or under-fill to secure devices when performing a second side reflow on these ADI devices.

Attachment I, continued

