

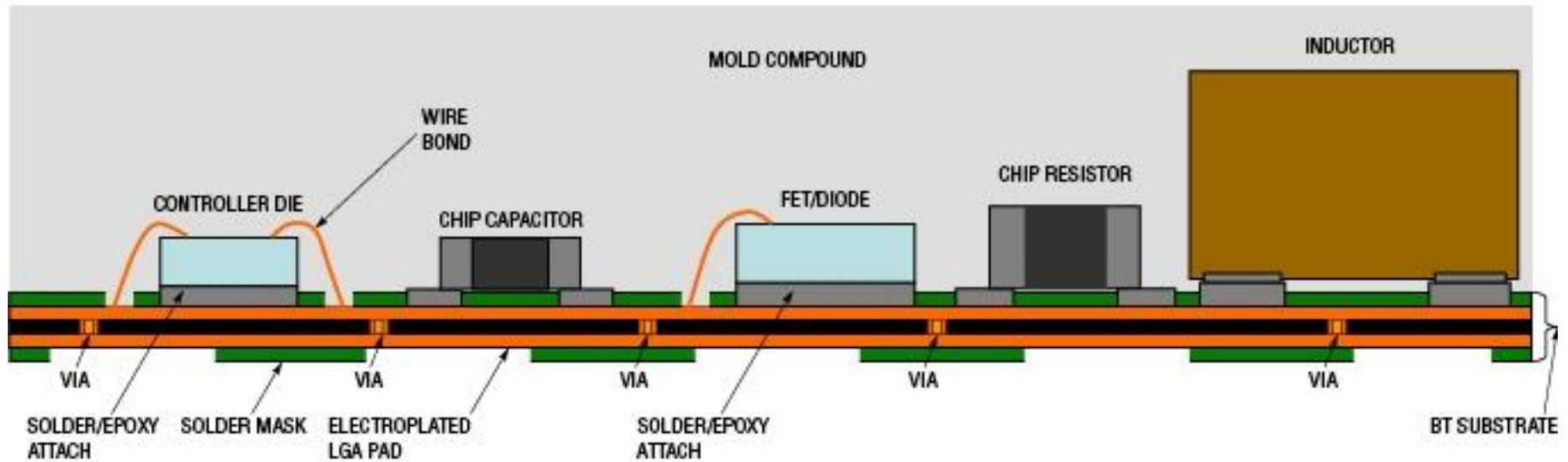
# **Assembly Considerations for Linear Technology $\mu$ Module™ LGA Packages**

**September 2016**

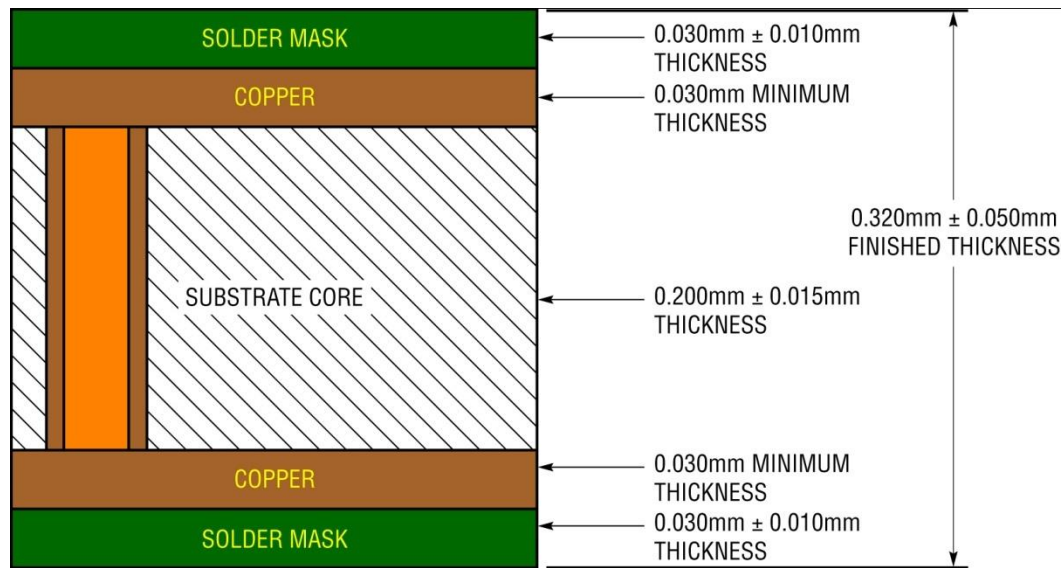
# Outline

- Package Construction
- PCB Design Guidelines
- Moisture Sensitivity, Pack, Ship & Bake
- Board Assembly Process
  - Screen Print
    - Stencil Design
    - Solder Paste, Key Process Parameters
  - Placement
  - Reflow Profile
  - Cleaning
  - Removal and Rework
- FAQs

## $\mu$ Module™ LGA Package Construction (Not To Scale)



# Substrate Construction



All dimensions in mm

REF: LTM4600 HIGH PERFORMANCE SUBSTRATE

Ni/Au Plating

SOLDER MASK = Taiyo ink PSR 4000

CORE = Mitsubishi Gas Chemical CCL-HL-832

Ni = 3  $\mu\text{m}$  minimum (5  $\mu\text{m}$  nominal)

Au = 0.3 to 0.8  $\mu\text{m}$  (0.5 $\mu\text{m}$  nominal)

# PCB Design Guidelines

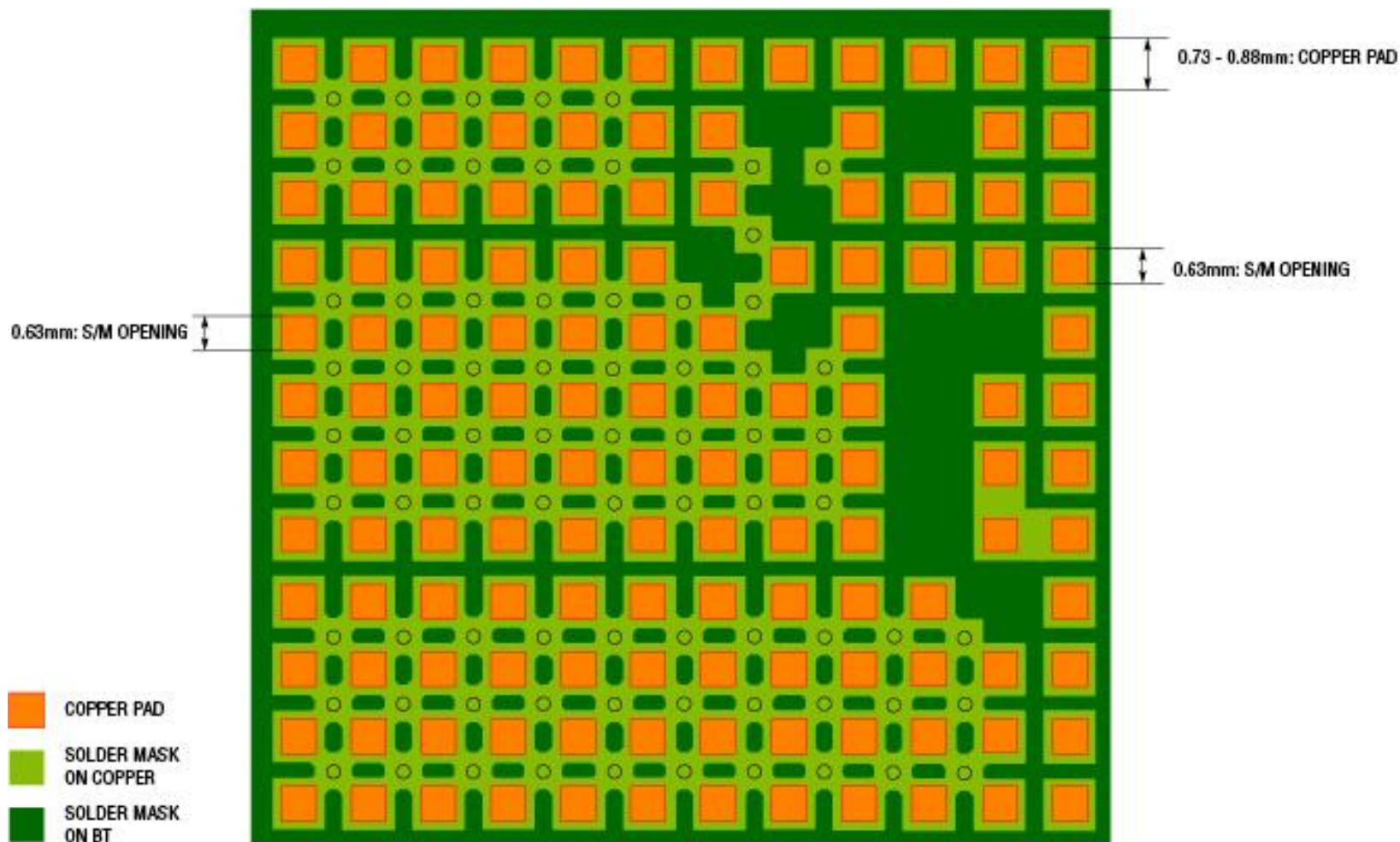
- **μModule LGA pad**
  - All pads are solder mask defined (SMD)
  - 0.63 mm opening
  - 2 devices have larger pad openings
    - LTM4604: 0.889 mm (35 mils)
    - LTM4608 : 0.762 mm (30 mils)
  - Both devices have equivalent packages with standard pad size (LTM4604A, LTM4608A)
  - Recommend using LTM4604A and LTM4608A over LTM4604 and LTM4608 respectively for new designs
- **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 0.63 mm)
  - For signal pins (SMD)
    - Metal Pad Size 0.73 - 0.88 mm
    - Solder mask opening 0.63 mm
  - Vias between pads (on the planes) on top layer
  - No issue with reliability (all solder joint reliability data on μModule devices using SMD pads on package and PCB)
- **Non solder mask defined (NSMD) pads**
  - Recommended Pad Layout
    - 0.63 mm pad size
    - 0.73 mm minimum solder mask opening on NSMD pads
  - If some pads are NSMD and some are SMD (on planes), ensure that the SMD pad opening is 0.63 and NOT 0.73 mm – Refer to Figures in the next few pages
- **Pad finish on PCB**
  - OSP, ENIG recommended
  - Immersion Ag
    - Check for any dendritic growth with moisture
  - Immersion Sn
    - Oxidation issues



# Solder Mask Defined Pads

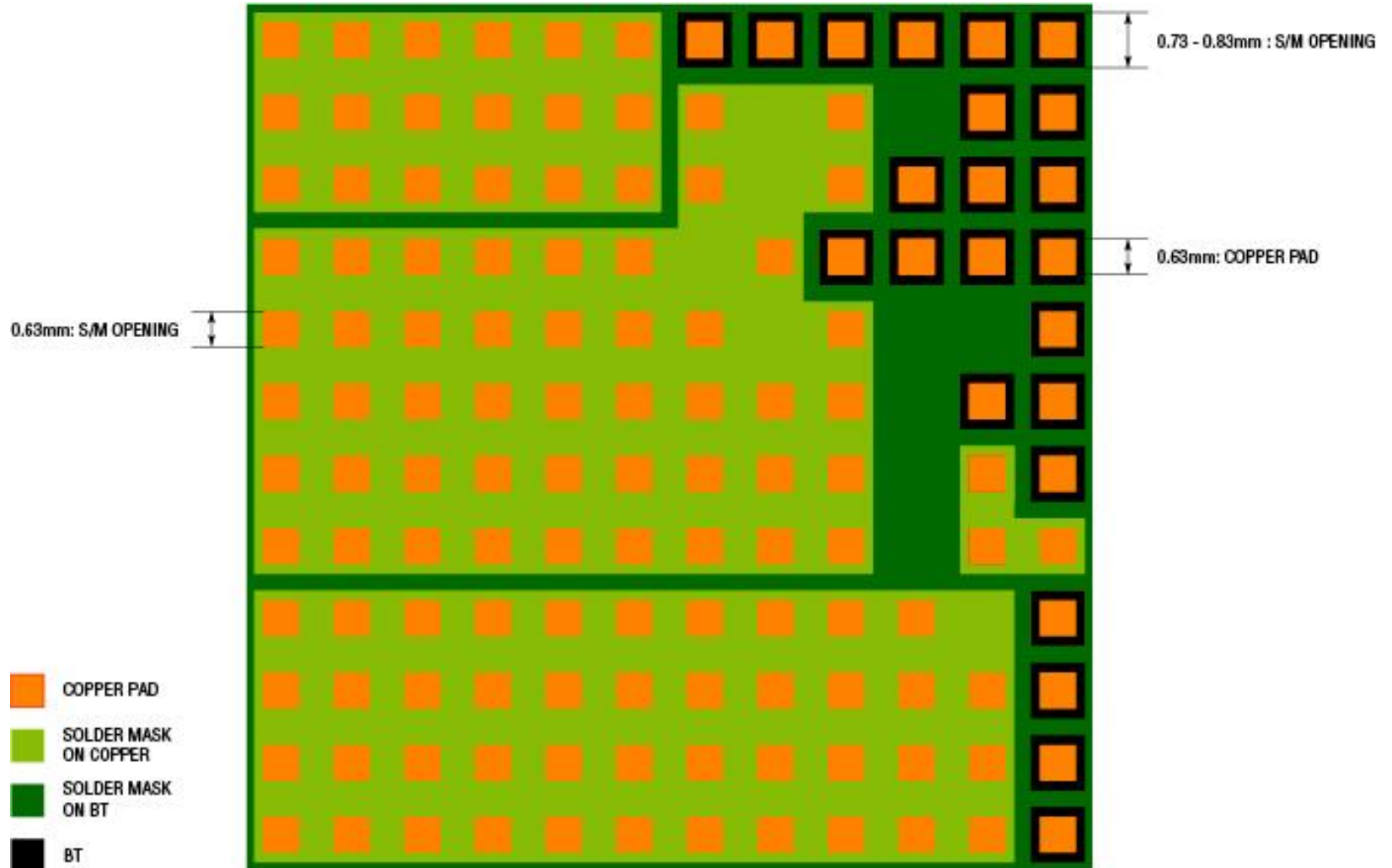
(interstitial vias - thermal relief)

Recommended PCB Pad Layout



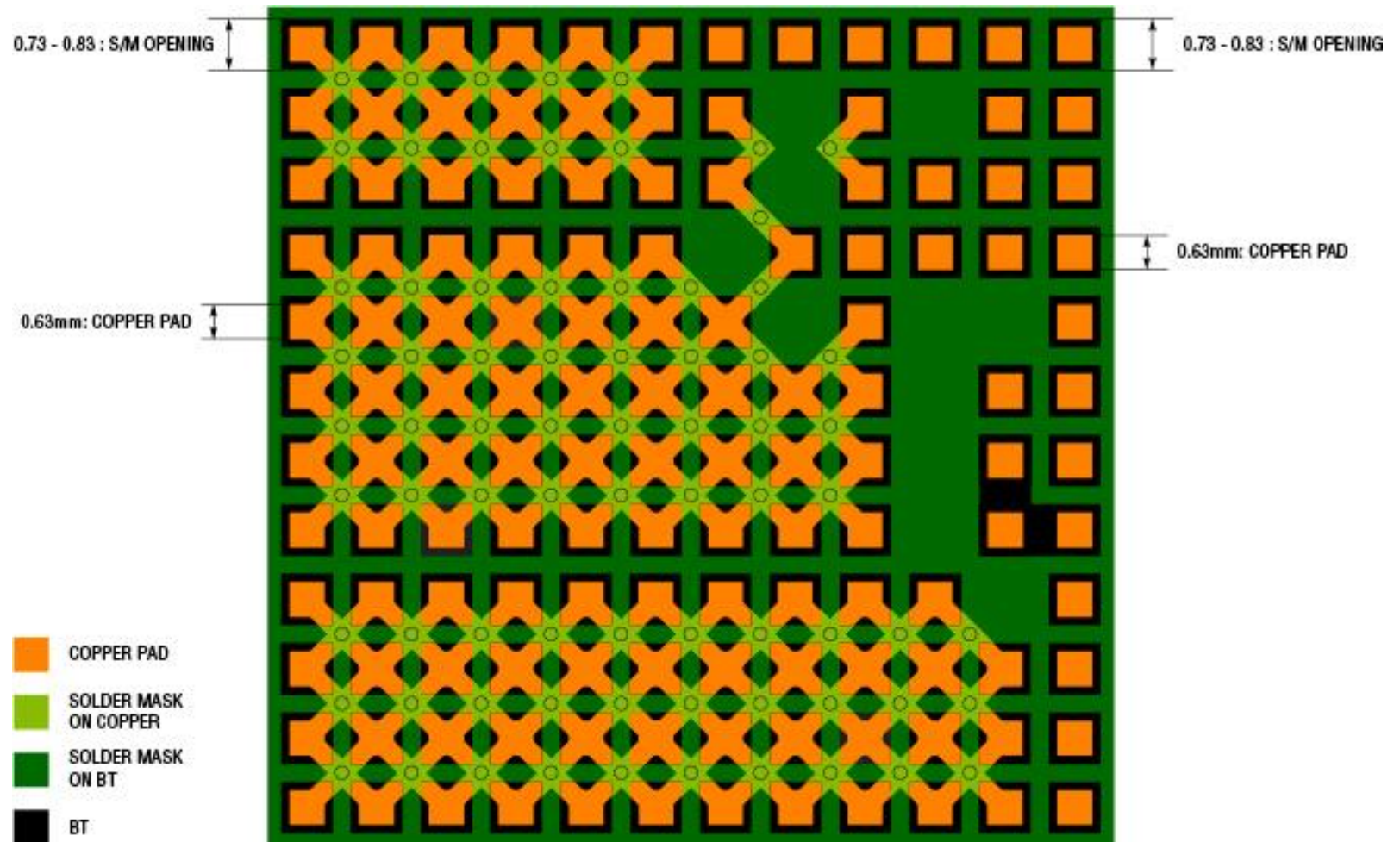
(Also see PCB Plane Separation Slide)

# Mixed Pads (SMD and NSMD)





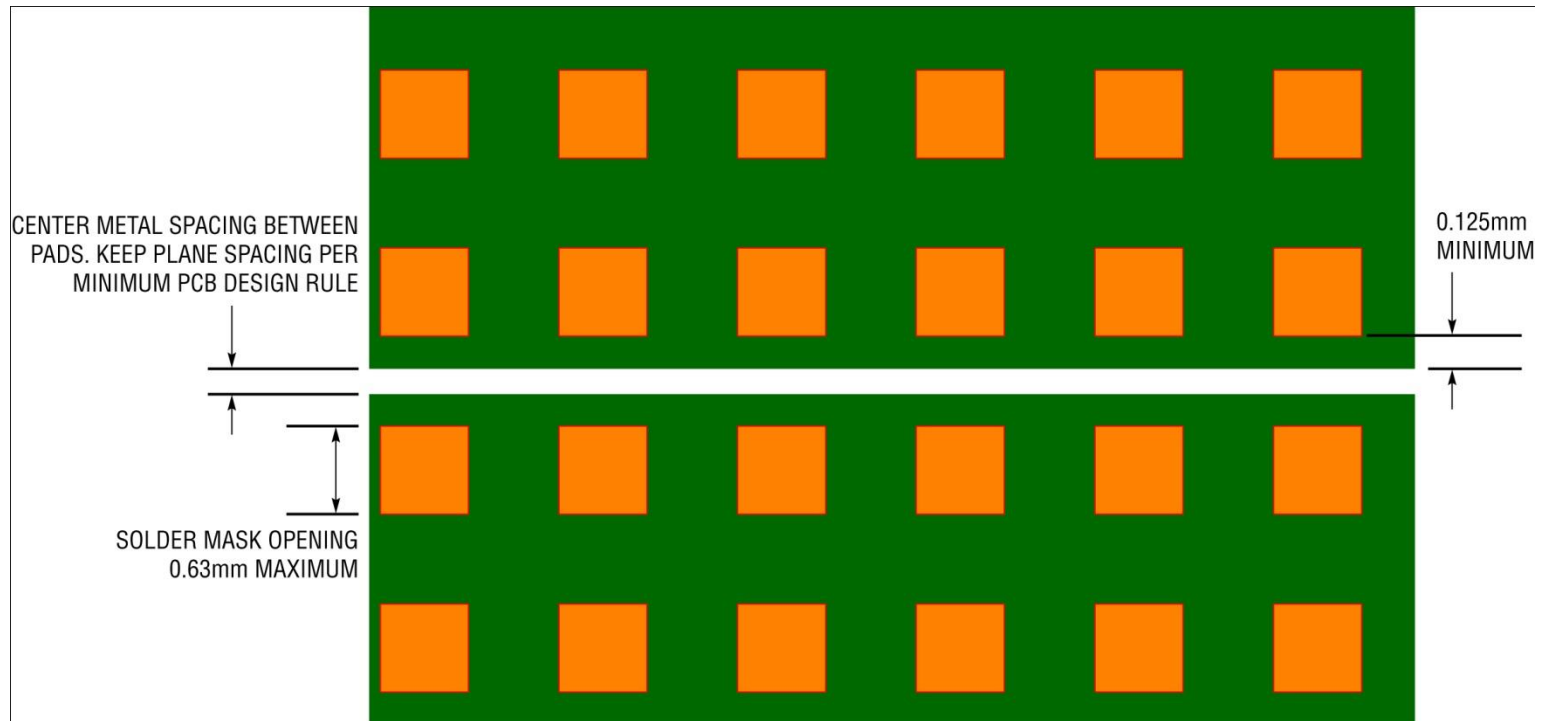
# NSMD (interstitial vias - thermal relief)



Thermal relief is used by some customers on the power/ground planes. Customers need to ensure that the resulting thermal relief topology does not cause solder balling on the vias.

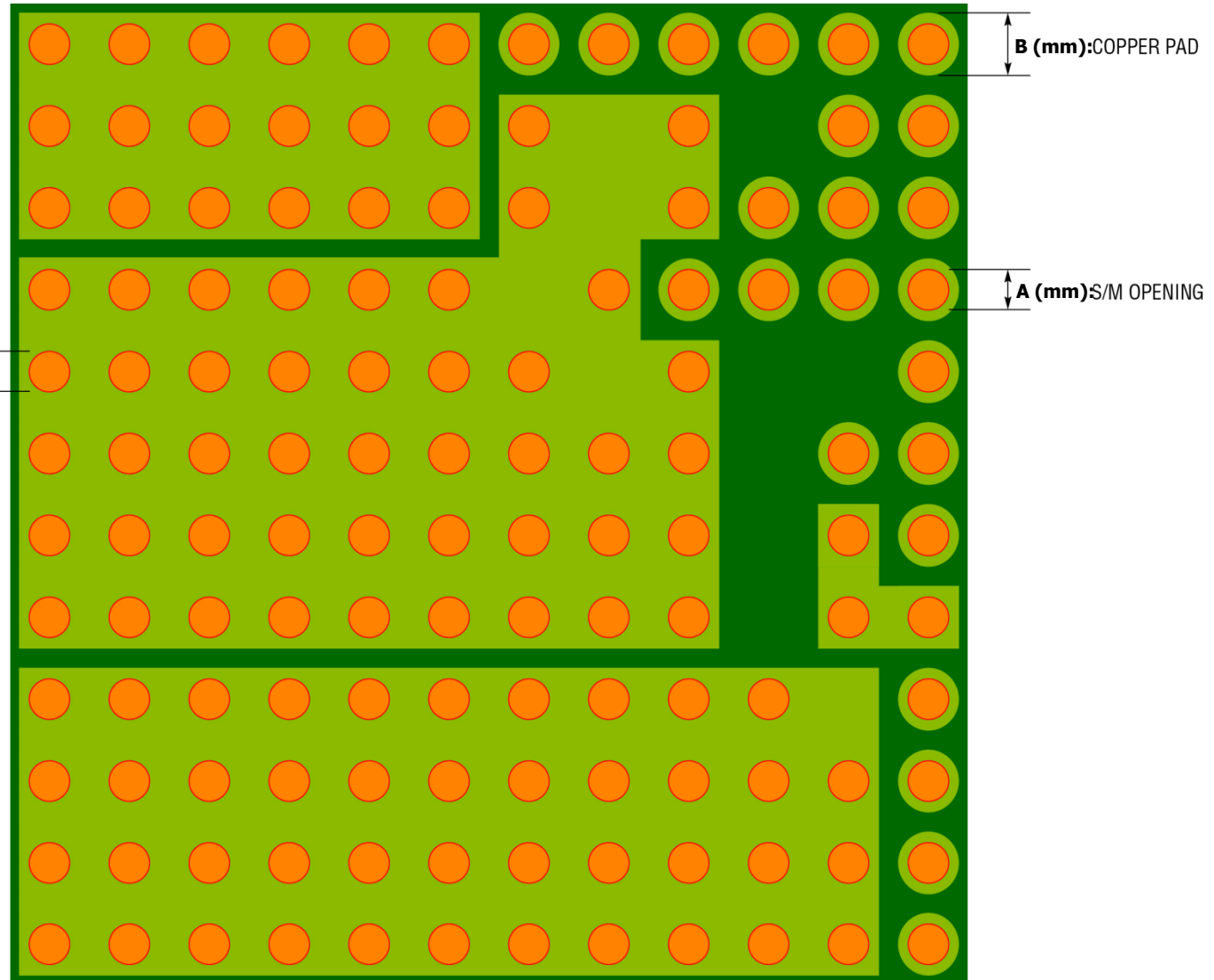
# PCB Plane Separation

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



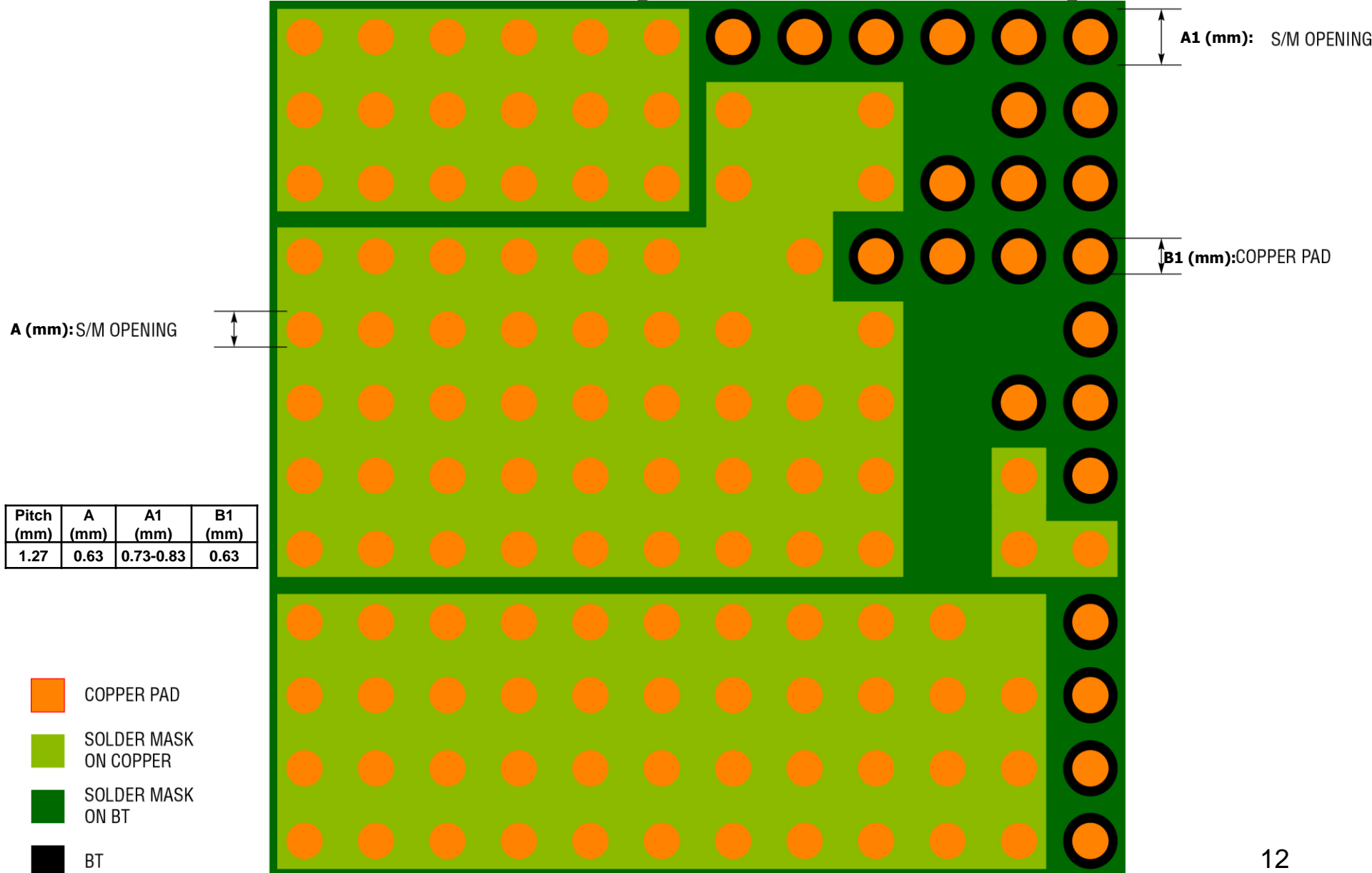
# Solder Mask Defined Pads

## Recommended PCB Pad Layout

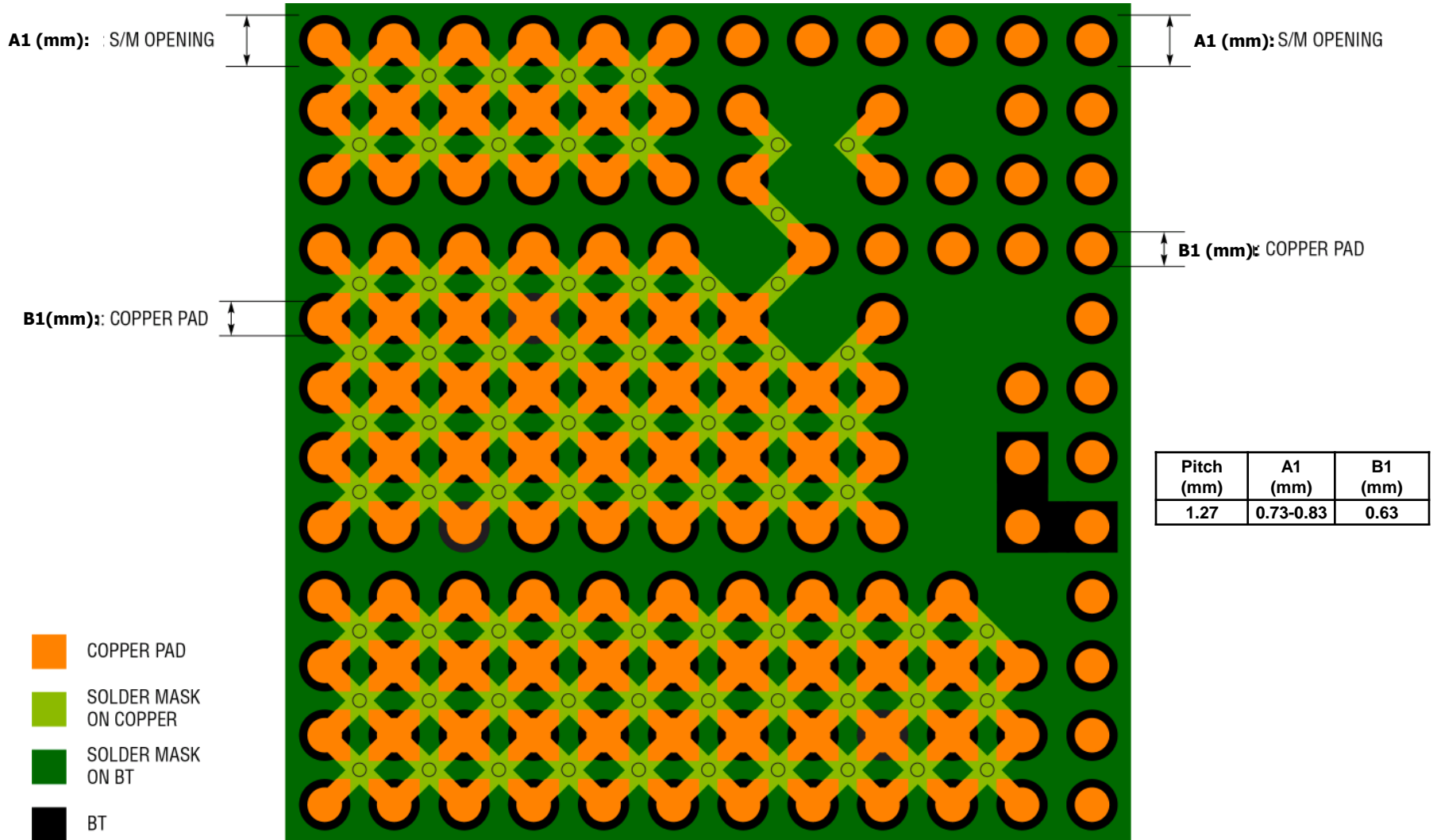


(Also see PCB Plane Separation Slide)

# Mixed Pads (SMD and NSMD)

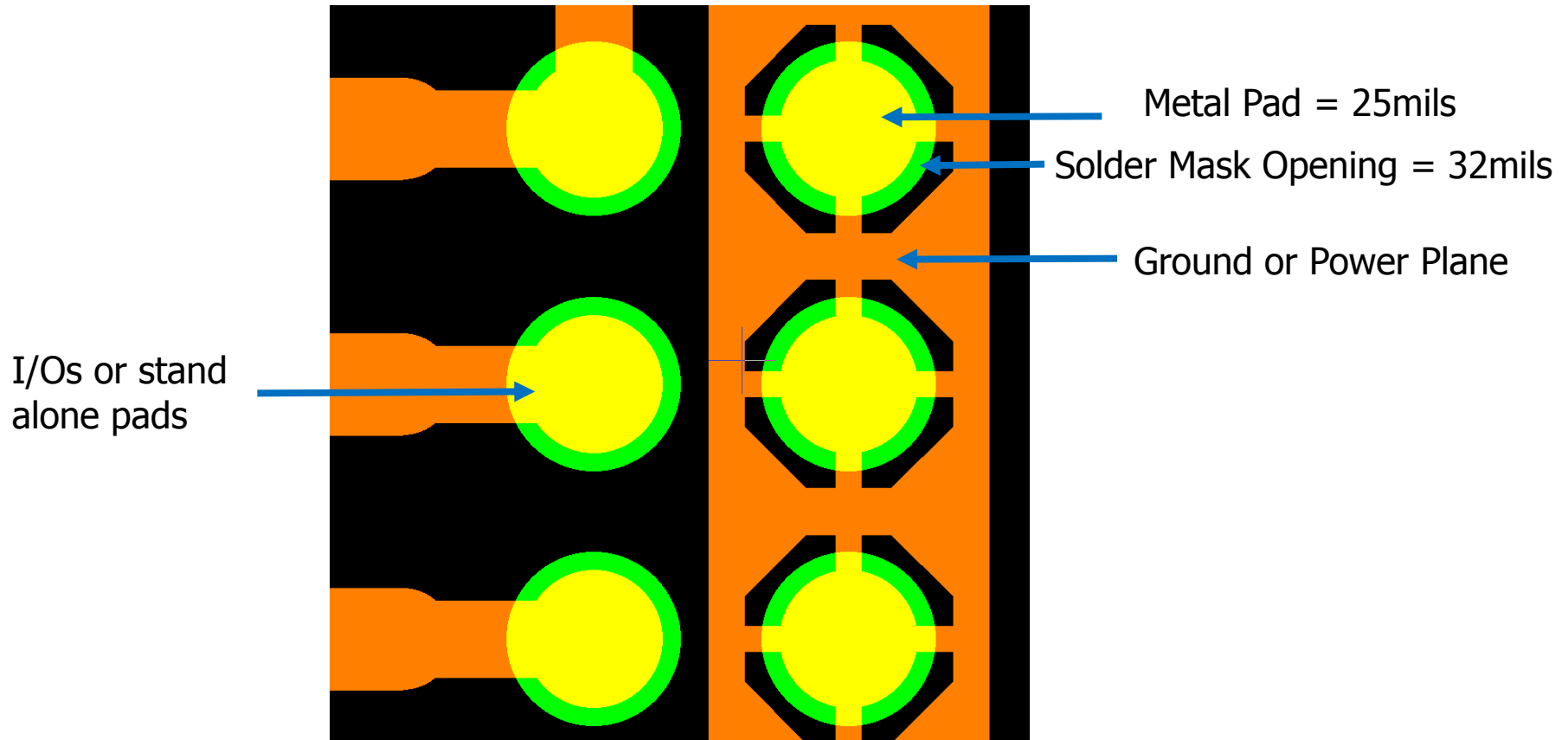


# Thermal Relief: NSMD



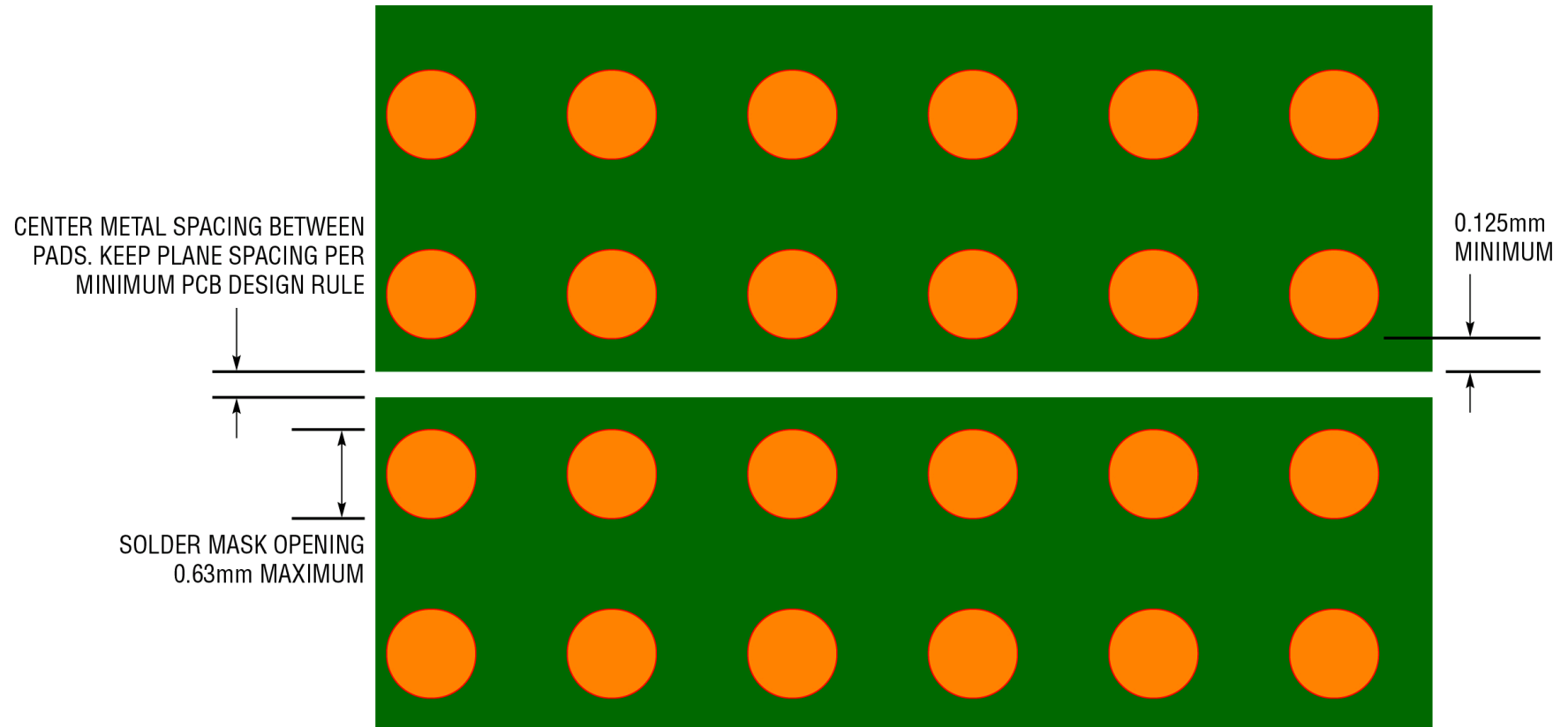
Thermal relief is used by some customers on the power/ground planes. Customers need to ensure that the resulting thermal relief topology does not cause solder balling on the vias.

# LTM2884 Pad Design Guideline



# PCB Plane Separation

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, Pack, Ship & Bake

- $\mu$ Module products meet MSL 3 or 4 of the JEDEC specification J-STD-020D.1 March 2008
- LTC ships all  $\mu$ 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 LTC)
  - Tape & Reel (**No parts in Tape & Reel are shipped from LTC; 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 LTC)
- 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”



# Solderability Test

- LTC  $\mu$ Module products cannot be checked for solderability using the solder dip method
- Solder paste needs to be screened onto the LGA pads and the part taken through reflow furnace (Surface mount Process simulation test per JEDEC spec “Solderability” JESD22-B102D)

# Stencil Design Recommendation

- Stainless steel laser cut stencils recommended
- Recommended stencil thickness 0.125 mm (5 mils)
  - Recommend slightly smaller stencil aperture than the pad opening (especially for SMD pads)
  - Stencil Opening: refer to Table below
    - To prevent paste from contacting solder mask
  - Solder volume: refer to Table below
  - 4 mil thick stencil not recommended (due to low stand off)
  - Corner radius of 0.06 mm on the aperture recommended
- Stencil area ratio ( $W/4t$ ) > 0.66 (not an issue for this aperture size)  
where  $W$  = Pad width,  $t$  = Stencil thickness

| SQUARE PADS                                      | PAD Size | STENCIL opening | Stencil Area       | % area | %linear | Paste Vol          |
|--|----------|-----------------|--------------------|--------|---------|--------------------|
|  | (mm)     | (mm)            | (mm <sup>2</sup> ) |        |         | (mm <sup>3</sup> ) |
| <b>All devices</b><br>(except LTM4604 & LTM4608) | 0.63     | 0.6             | 0.36               | 91%    | 95%     | 0.045              |
| LTM4608  | 0.762    | 0.72            | 0.52               | 89%    | 94%     | 0.065              |
| LTM4604  | 0.889    | 0.84            | 0.71               | 89%    | 94%     | 0.088              |
| <b>ROUND PADS</b>                                |          |                 |                    |        |         |                    |
| <b>All devices</b>                               | 0.63     | 0.6             | 0.28               | 91%    | 95%     | 0.035              |

note: stencil thickness is 5 mils

# Screen Print

- Solder Paste
  - Low voiding paste
  - Type III or IV
  - Paste types used at Linear or by our customers include, but are not limited to,
    - Sn/Pb Kester 531, AIM WS483, Alpha OM-5300
    - 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

# Placement

- Typical placement systems used for any BGA package are acceptable
- The LGA part needs to be pushed into the solder paste to achieve good contact of solder paste onto the LGA pads (pads are solder mask defined)
  - Adjustments to the setup on placement systems are done using force as a variable or Z height from the PCB as reference
  - Need to find the correct setting so that paste is not squeezed out of the pad, but at the same time ensure the contact with the LGA pad
    - Can be checked with X-ray before and after screen printing (before reflow)
  - This ensures good solderability and less voiding

# 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  $\mu$ Module devices.
- Check that the solder paste vendor recommended profile conforms to LTC recommendations
  - If the LTC 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**

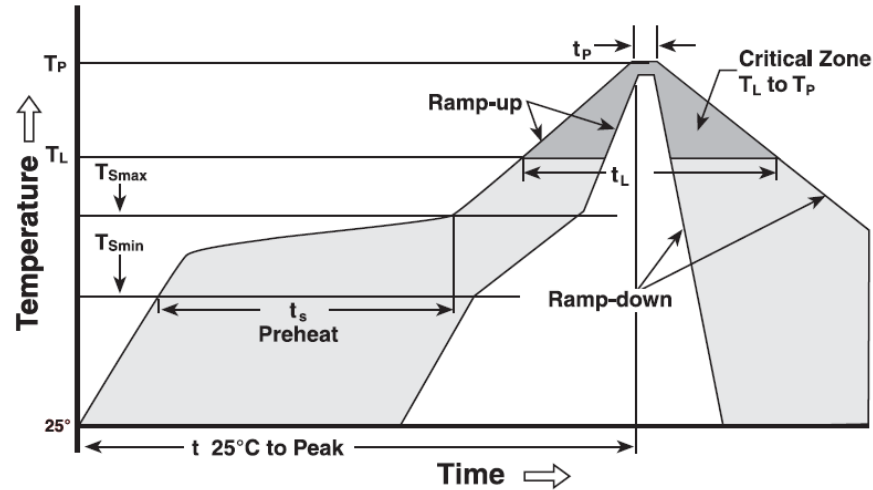
| PACKAGE THICKNESS | VOLUME                | VOLUME                                     | VOLUME                      |
|-------------------|-----------------------|--|-----------------------------|
|                   | < 350 mm <sup>3</sup> | 350 mm <sup>3</sup> - 2000 mm <sup>3</sup> | $\geq$ 2000 mm <sup>3</sup> |
| < 1.6mm           | 260 + 0 °C            | 260 + 0 °C                                 | 260 + 0 °C                  |
| 1.6mm - 2.5mm     | 260 + 0 °C            | 250 + 0 °C                                 | 245 + 0 °C                  |
| $\geq$ 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 <sup>3</sup> | $\geq$ 350 mm <sup>3</sup> |
| < 2.5mm           | 240 + 0/-5 °C         | 225+ 0/-5 °C               |
| $\geq$ 2.5mm      | 225 + 0/-5 °C         | 225 + 0/-5 °C              |

- **2 sided reflow is not recommended for LTM2881, LTM2882, LTM2883 and LTM2884. Please refer to ATTACHMENT I for further information.**

# Reflow Profiles



| Profile Feature                              |  | Lead-Free Solder | Leaded Solder    |
|--|--|------------------|------------------|
| Pre-heat                                     | Min Soak Temperature<br>Min ( $T_{Smin}$ ) | 150°C            | 100°C            |
|  | Max Soak Temperature<br>( $T_{Smax}$ )     | 200°C            | 150°C            |
|  | Soak Time ( $t_s$ )                        | 60-120 seconds   | 60-120 seconds   |
| Reflow                                       | Liquidus Temperature<br>( $T_L$ )          | 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 ( $T_{Smax}$ 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      |

# Cleaning

- No clean paste recommended
- Water soluble paste has been used successfully with the  $\mu$ Module packages
  - Use a saponifier or ultrasonic cleaning with water
  - Use DI water spray system to further clean under the LGA

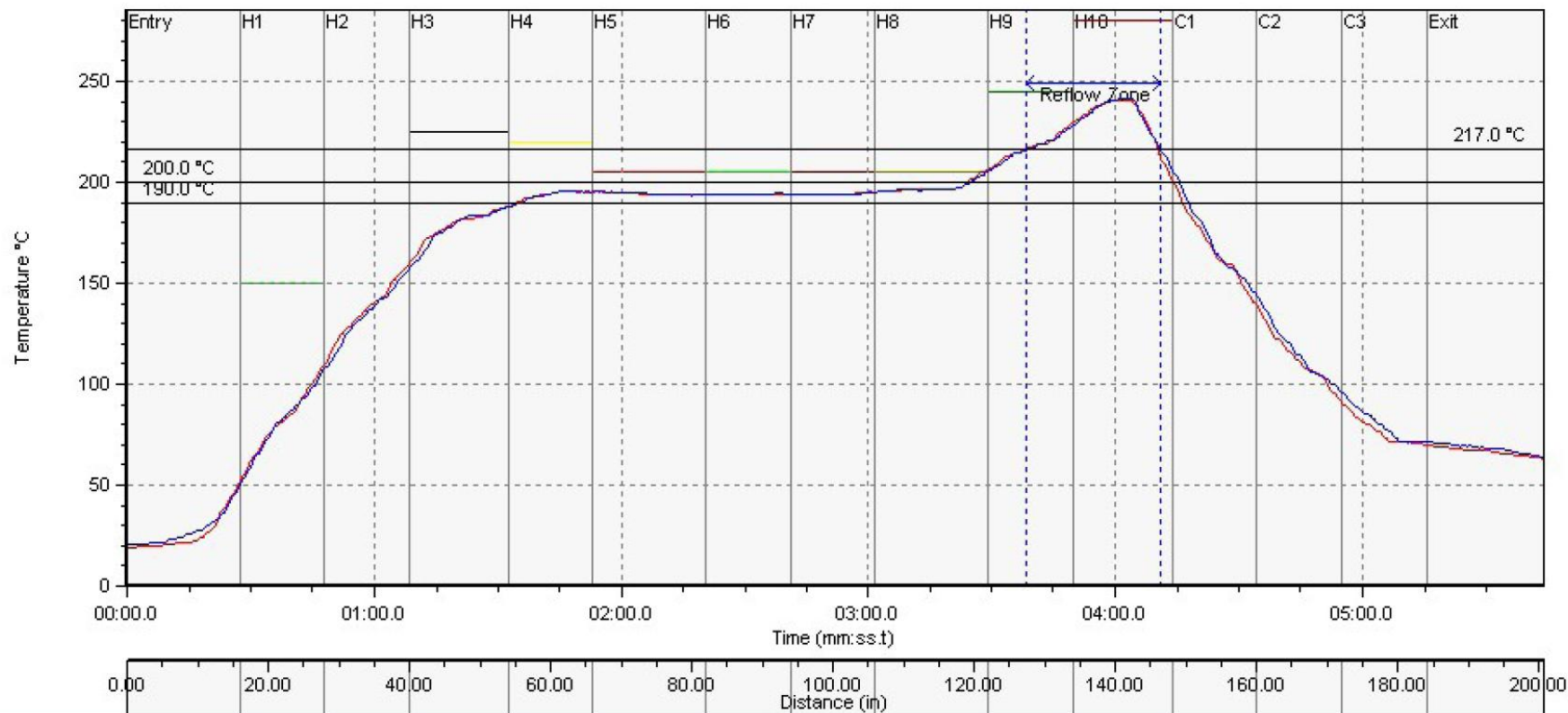
# Solder Joint Voiding

- No IPC standard for LGA pad voiding criteria
- LTC has tested devices with solder joint voids up to 30% and no reliability issues seen
- LTC recommends using a 25% maximum void criteria for solder joints
- Correct Z height adjustment ensuring contact of paste and LGA pad and soak profiles minimize solder joint voiding
- PCB baking at 125 deg C for at least 4 hours will minimize solder joint voiding
- If the recommended LTC or paste vendor profile results in >25% voiding, then use a soak profile during reflow (Profile with Thermocouple underneath the LGA)
  - 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



# LTM 4601 Soak Profile Example (Long Soak)

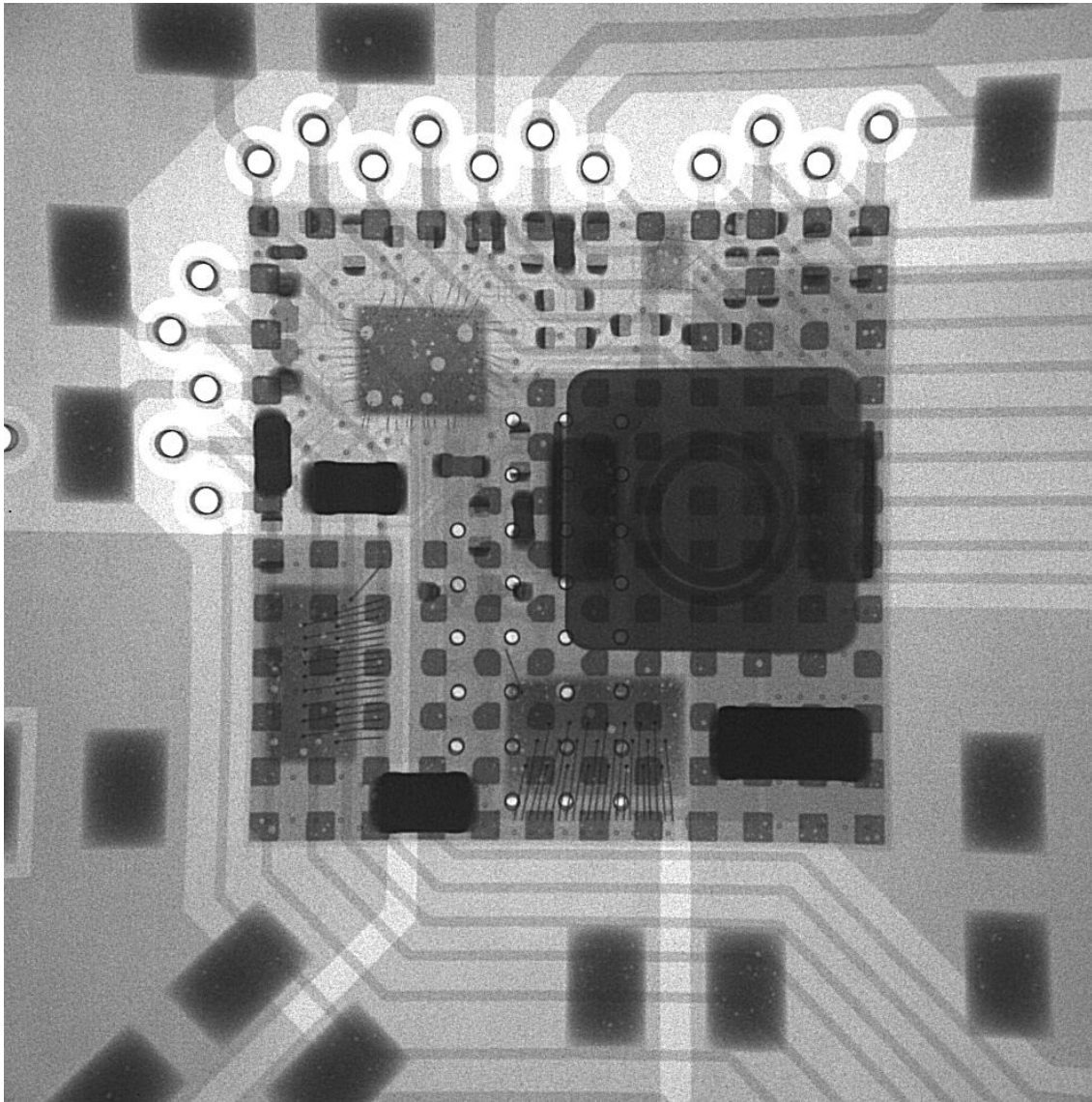
Solder Paste: AIM



## Reflow Results

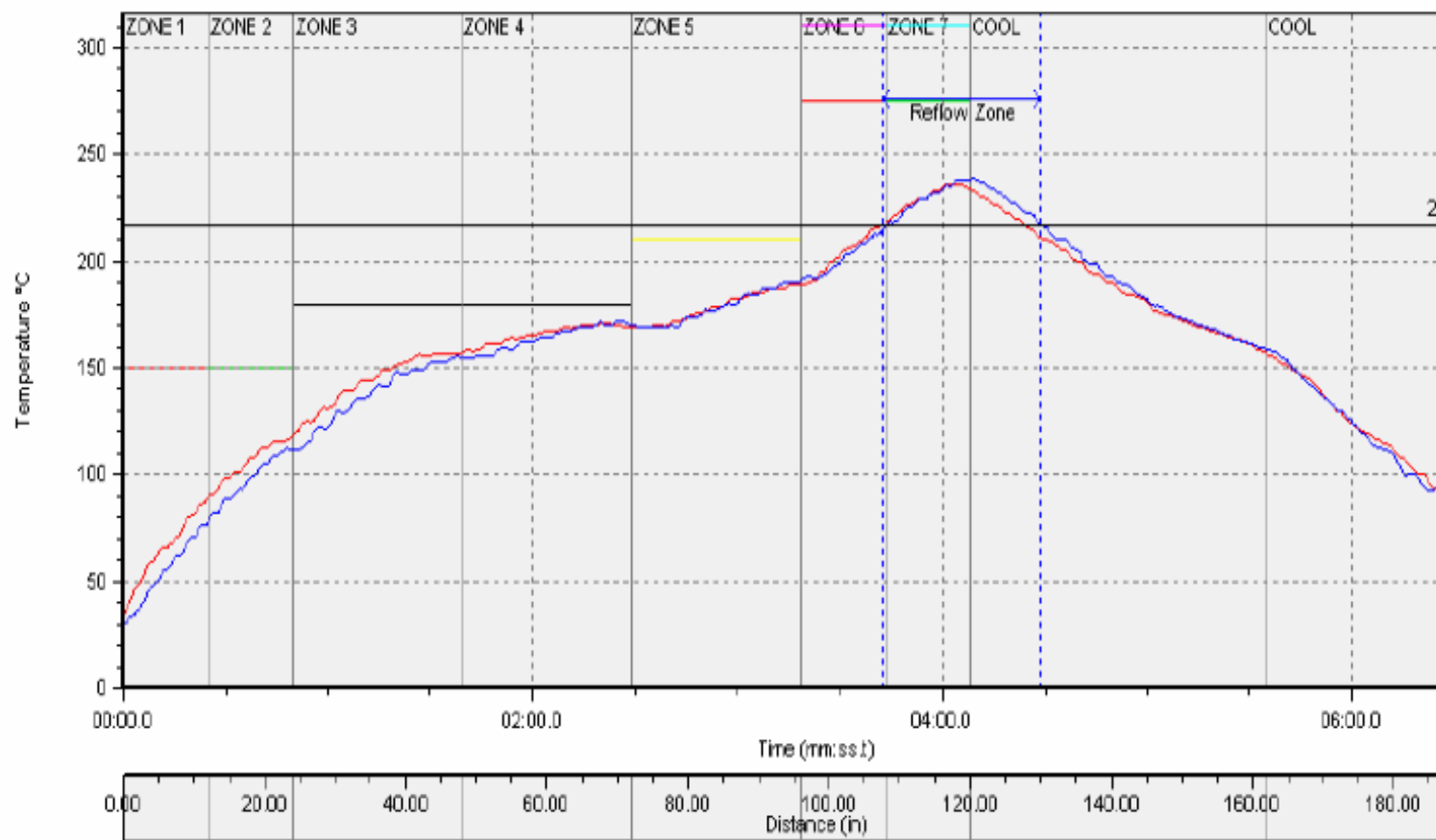
| Probe   | Positive Slope (°C/sec) | Positive Slope Time (mm:ss.t) | Rise Time (189.0 - 200.0°C) (mm:ss.t) | Time Above Liquidus (217.0°C) (mm:ss.t) | Peak Temperature (°C) | Delta T (°C) | Negative Slope (°C/sec) |
|---------|-------------------------|-------------------------------|---------------------------------------|---|-----------------------|--------------|-------------------------|
| #1 (°C) | 3.57                    | 00:26.0                       | 01:51.0                               | 00:32.0                                 | 241.5                 | ○ 0.5        | -4.52                   |
| #3 (°C) | 3.51                    | 00:28.0                       | 01:50.5                               | 00:32.5                                 | 242.0                 | ●            | -3.98                   |

# LTM 4601 Void monitor (Long Soak)



LGA joints show  
minimal voids

# LTM 4604 Profile Example (Short Soak)



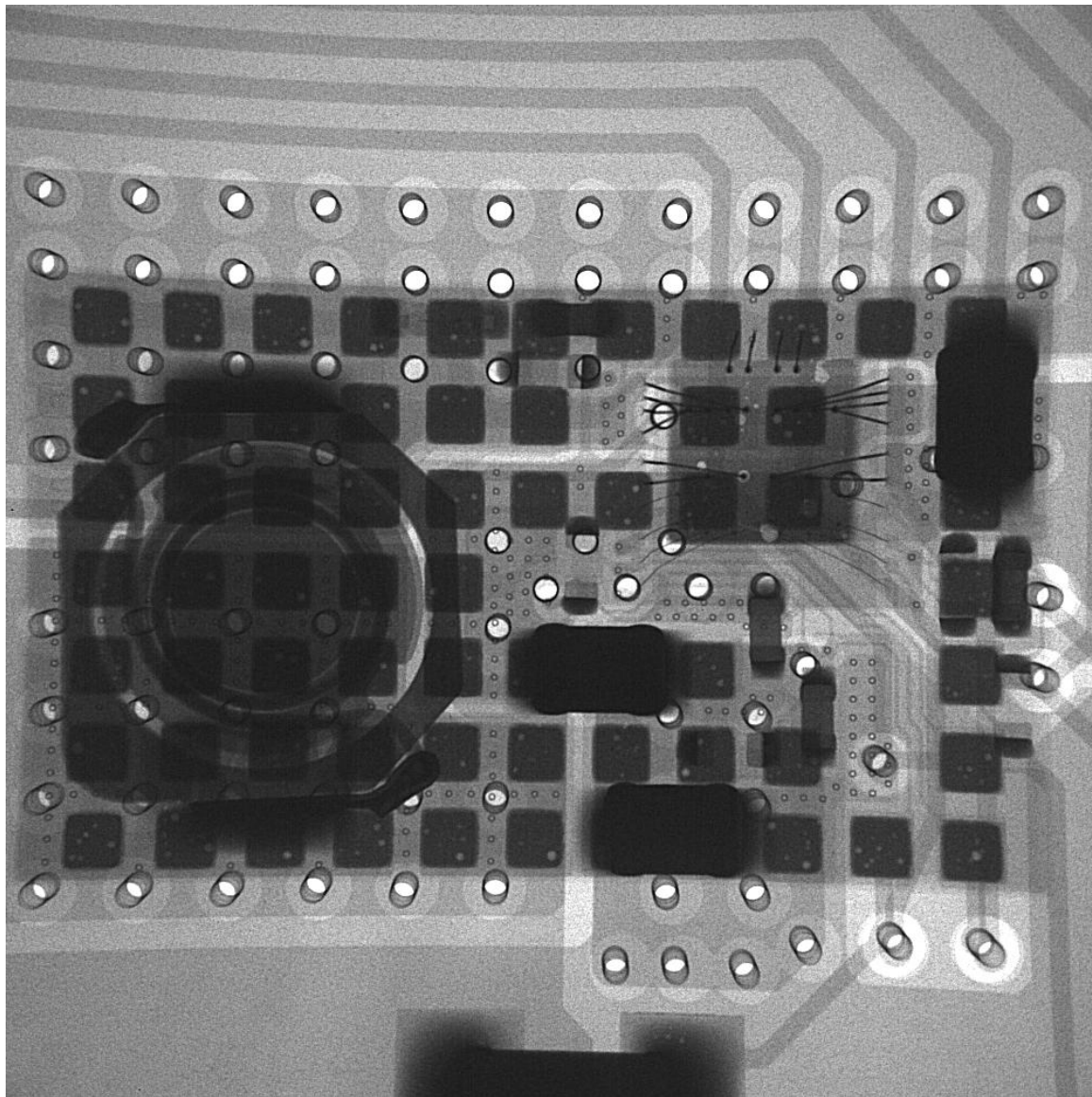
## Reflow Results

| Probe   | Positive Slope (°C/sec) | Positive Slope Time (mm:ss.t) | Rise Time (150.0 - 176.0°C) (mm:ss.t) | Time Above Liquidus (217.0°C) (mm:ss.t) | Peak Temperature (°C) | Delta T (°C) | Negative Slope (°C/sec) |
|---------|-------------------------|-------------------------------|---------------------------------------|---|-----------------------|--------------|-------------------------|
| #1 (°C) | 2.88                    | 00:05.0                       | 00:55.0                               | 00:42.0                                 | 236.0                 | ○ 2.5        | -1.82                   |
| #3 (°C) | 2.44                    | 00:07.5                       | 00:49.5                               | 00:46.0                                 | 238.5                 | ●            | -1.64                   |



# LTM 4604 Void Monitor

## (Short Soak)



LGA joints show  
minimal voids

# Rework

## Component ( $\mu$ Module device) Removal

- Determine the failure mode from the board and at what operation the defect 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 of the moisture barrier bag opening prior to assembly or after baking the PC board assembly. Bake the PCB for 24 hours at 125°C
  - 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 is baked properly, the solder does not spread and it is contained within the soldered pad

# Rework

## Component ( $\mu$ Module device) Removal

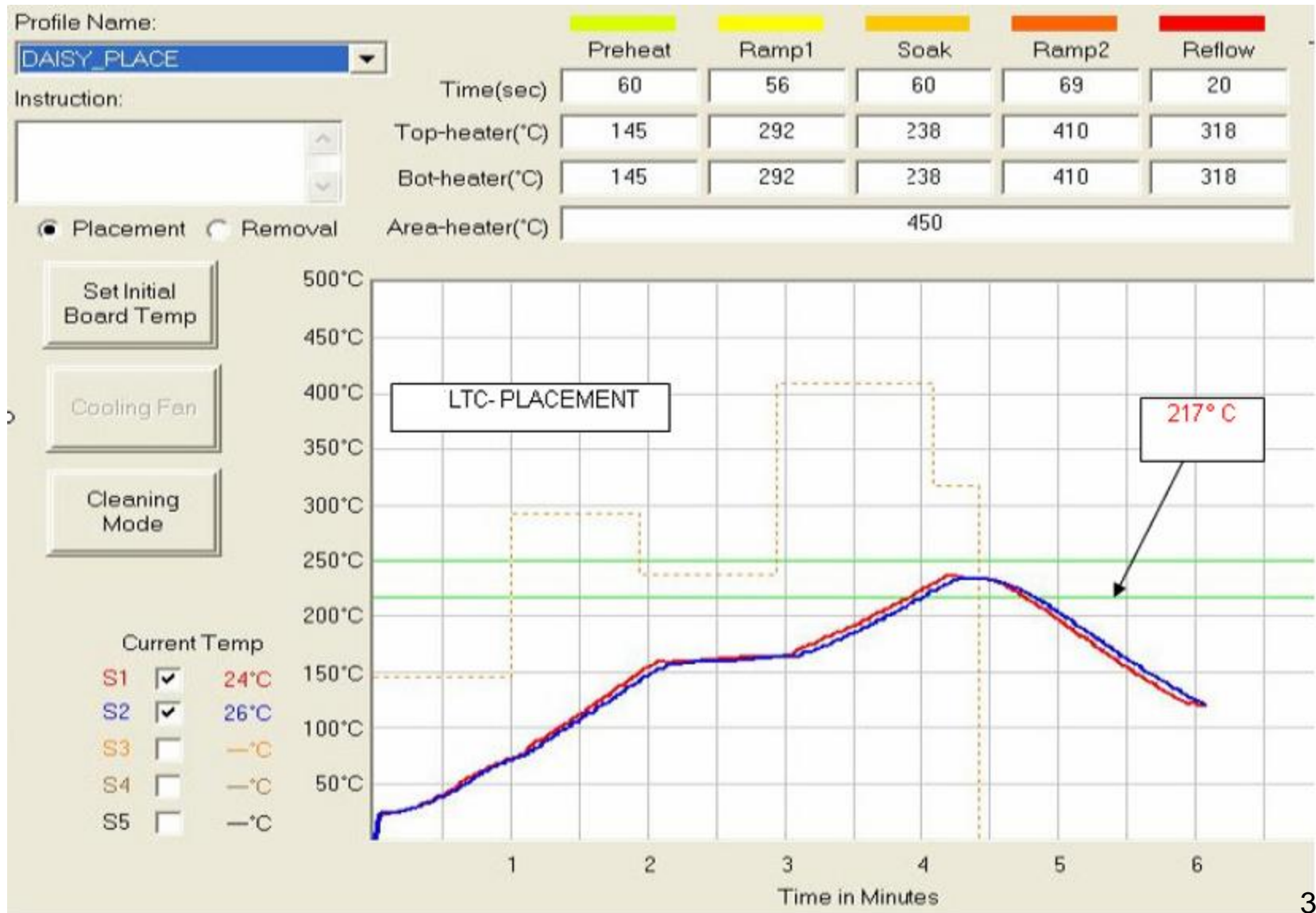
- Use a BGA rework station capable of profiling top and bottom of Module
  - Handheld heat guns or IR-only rework stations should not be used
  - Use appropriate heat shielding of sensitive components in proximity to the  $\mu$ modules
  - The profile is done with a thermocouple on top of the part and 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 Pb paste 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 Attachment

- 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
- Inspection of solder joints using X-ray

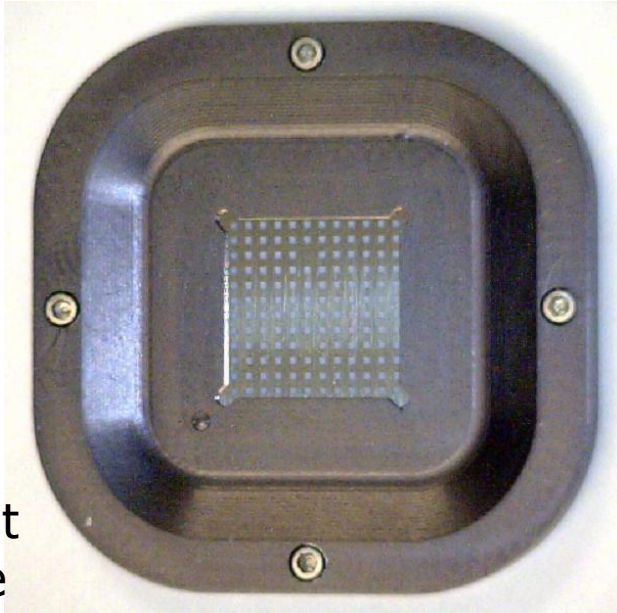
# Rework Profile (Pb free)

## – Removal and Attachment

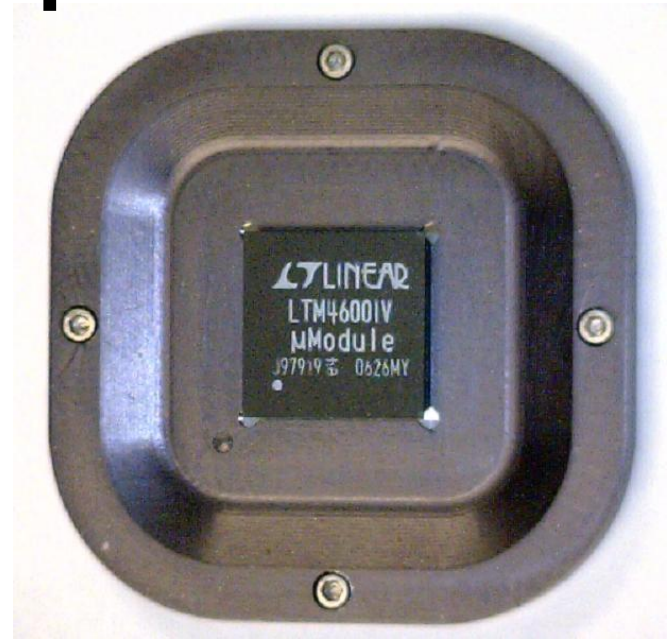




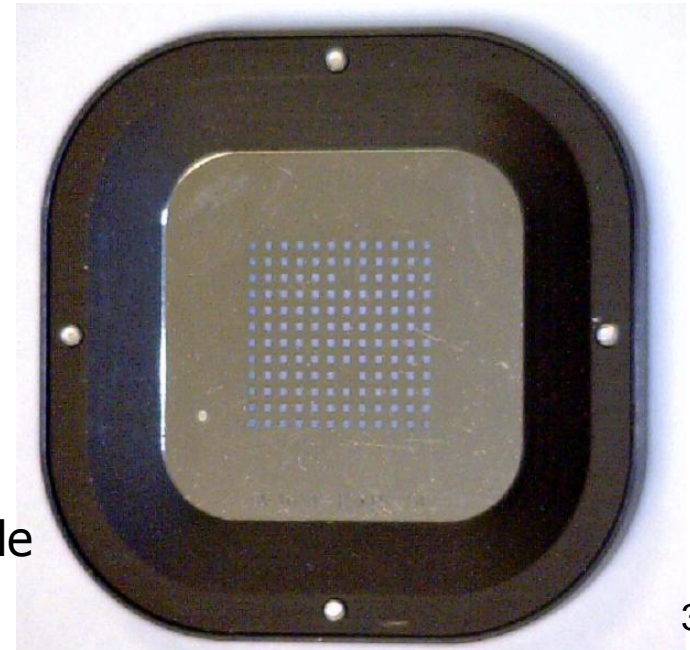
# Micro Stencil, Component Placement



Component  
(Nest) side



Place component in the nest  
Hold component with one hand  
Flip the fixture  
Apply paste on print side



Print side

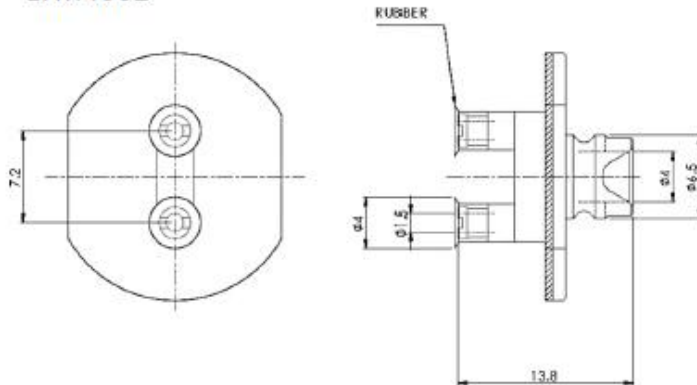
# SMT Nozzle, Pick n Place for Packages with Component(s) on Top

## Type 1: Inductor Pick-up

Nozzle design layout.

Panasonic Dual Tip Vacuum Pad Nozzle (Pitching 7.2mm)

LTM4662

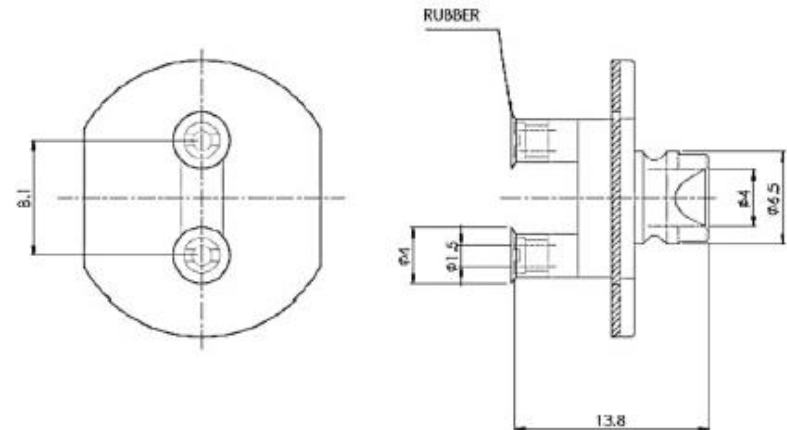


Bottom view

Side view

Panasonic Dual Tip Vacuum Pad Nozzle (Pitching 8.1mm)

LTM4678



Bottom view

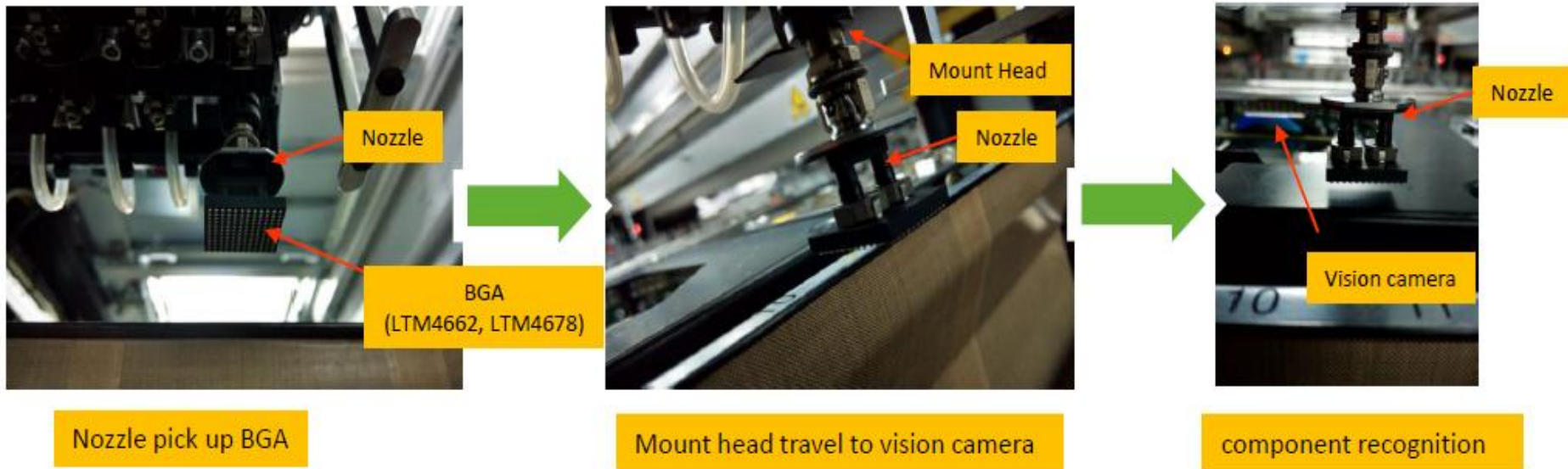
Side view



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

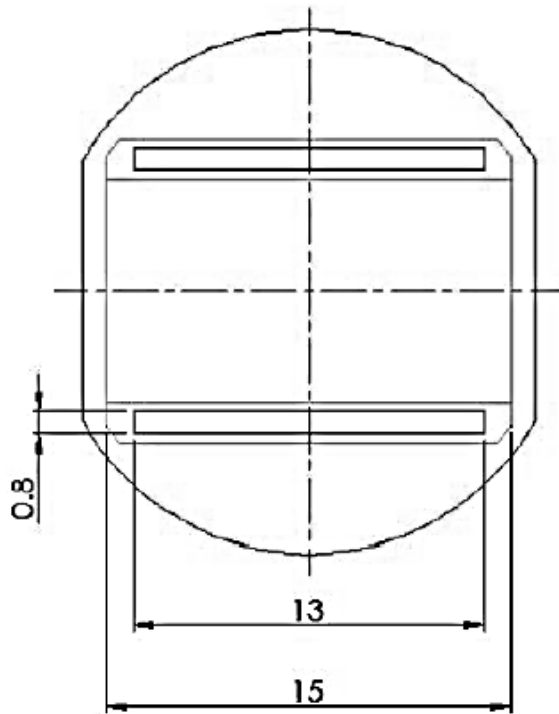
## Type 1: Inductor Pick-up

Nozzle pick up component and vision flows sequence .

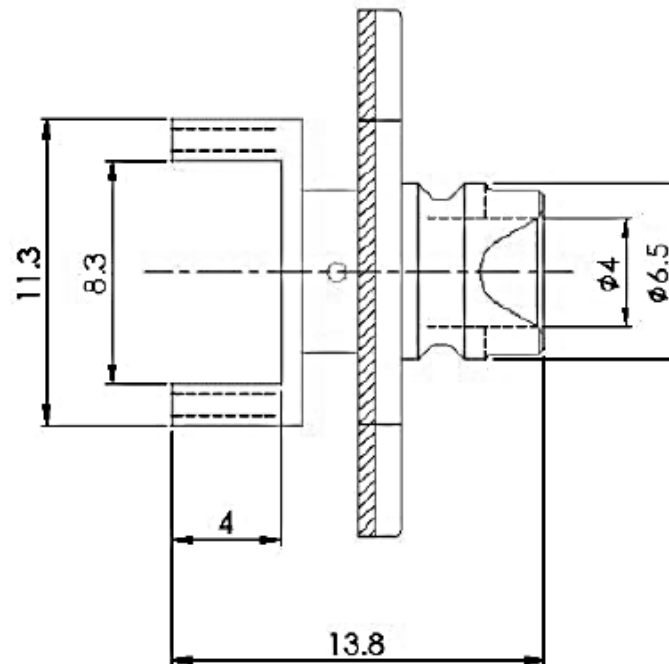


# SMT Nozzle, Pick n Place for Packages with Component(s) on Top

## Type 2: Package Body Pick-up



Bottom view

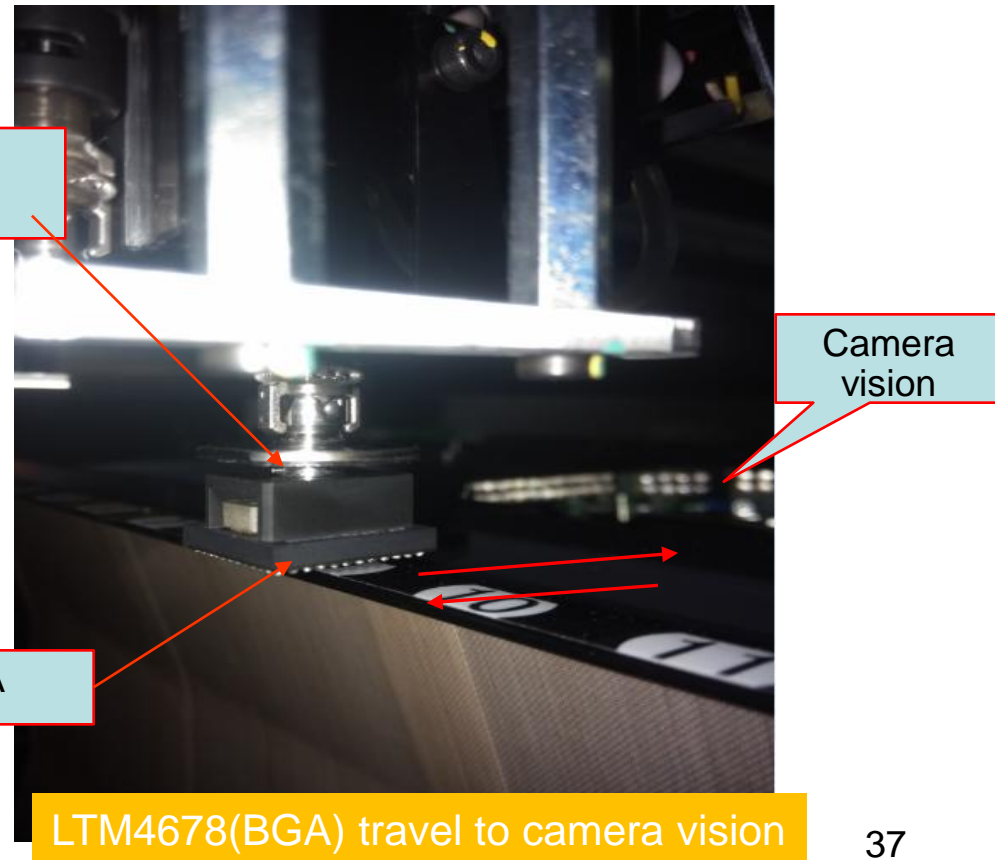
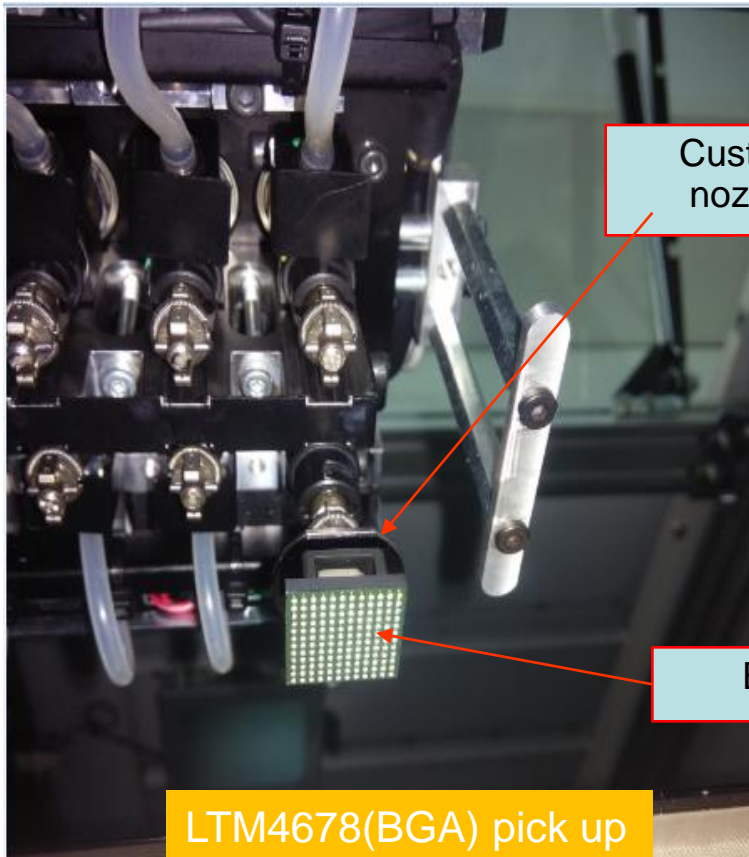


Side view



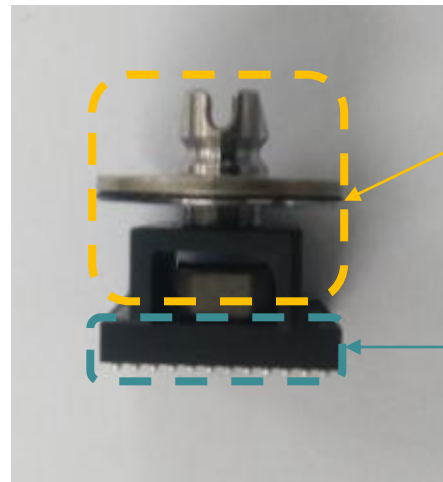
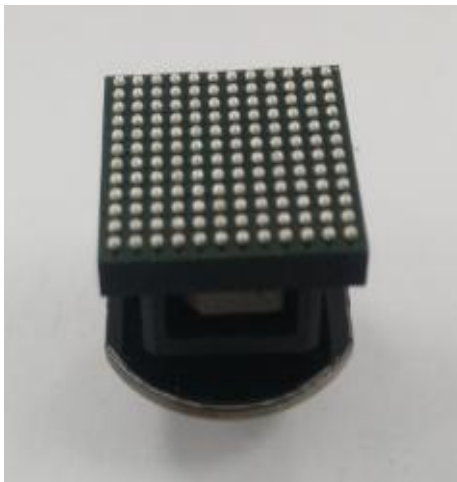
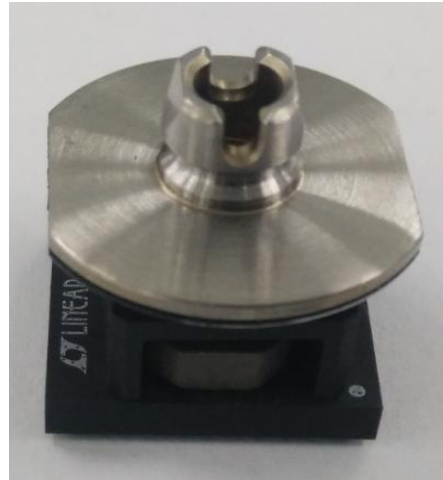
# SMT Nozzle, Pick n Place for Packages with Component(s) on Top

## Type 2: Package Body Pick-up



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

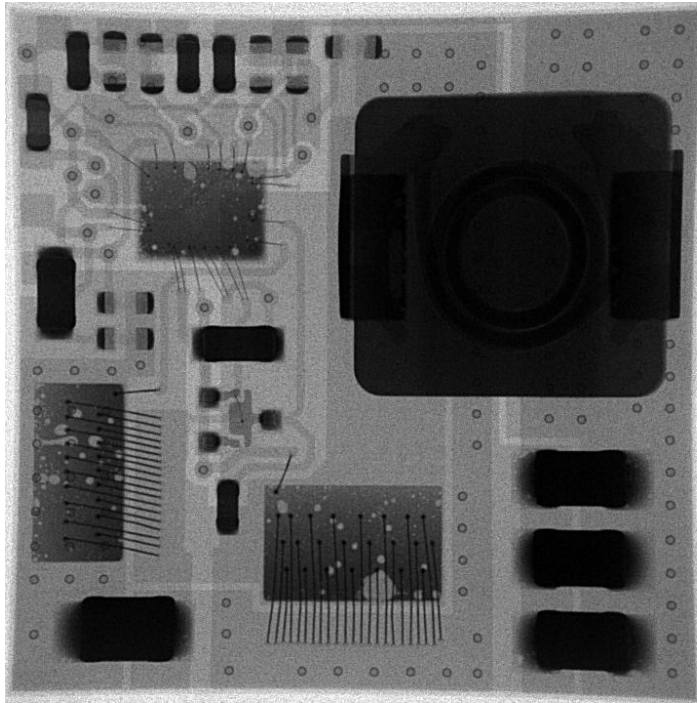
## Type 2: Package Body Pick-up



Custom  
nozzle

BGA

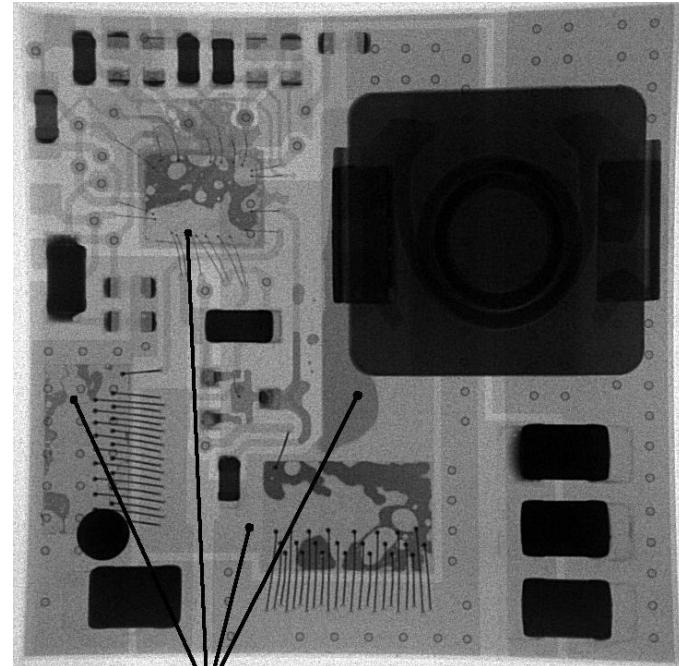
# X-ray inside the $\mu$ Module Device



Micro Module X-Ray following a correct reflow and rework procedure

## NO SHORTS

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



EXCESS HEAT ALONG WITH MOISTURE CAUSES POPCORN AND SUBSEQUENT SHORTING BETWEEN PASSIVE COMPONENTS

## SOLDER SHORTS INSIDE MODULE

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

# FAQs

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; Finefocus X-ray can also be used (need to have good training to differentiate the PCB solder joints from the solder inside the  $\mu$ Module device).
5. Can the  $\mu$ Module product be used on both sides of the PCB?
  - Yes, provided the total exposure time (out of bag to 2<sup>nd</sup> reflow) is less than 168 hrs
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 as shown in the prior slide



# FAQs

## 6. How to prevent shorting inside the module?

- Check the floor life of the parts (From out of sealed bag to reflow); If over 168 hours, 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)?
  - Bake the PCB for 24 hours at 125°C
  - If heat gun was used, temperature may be excessive (Do not use heat gun)
  - Profile the rework station and remove component

## 7. How and where to get mini-stencil?

- Photo stencil, Colorado Springs, CO
  - Phone 719-535-8544
  - Contact : Heather Marshall [hmarshall@photostencil.com](mailto:hmarshall@photostencil.com).
- The alignment block (2 pieces that hold the above stencils) comes from
  - 2Spec Engineering (alignment blocks), San Jose, CA
  - Phone 408-227-3200
  - Contact : Ty Mingione [Ty@2Spec.com](mailto:Ty@2Spec.com)

## 8. Can the removed module be reused?

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

# 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.

Linear Technology 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.

Linear Technology recommends that the suitability of all LGA and BGA  $\mu$ 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 LTC devices.

# ATTACHMENT I, cont'd

