Freescale Semiconductor Tape Ball Grid Array (TBGA) Overview
## Table of Freescale TBGA Configurations

<table>
<thead>
<tr>
<th>Body Size (mm)</th>
<th>Ball Pitch (mm)</th>
<th>Ball Count</th>
<th>Number of Perimeter Rows</th>
<th>Pkg Pad Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 x 31</td>
<td>1.00</td>
<td>500</td>
<td>5P</td>
<td>0.50</td>
</tr>
<tr>
<td>35 x 35</td>
<td>1.00</td>
<td>672</td>
<td>6P</td>
<td>0.45</td>
</tr>
<tr>
<td>37.5 x 37.5</td>
<td>1.00</td>
<td>740</td>
<td>6P</td>
<td>0.45</td>
</tr>
<tr>
<td>31 x 31</td>
<td>1.27</td>
<td>304</td>
<td>4P</td>
<td>0.60</td>
</tr>
<tr>
<td>35 x 35</td>
<td>1.27</td>
<td>352</td>
<td>4P</td>
<td>0.60</td>
</tr>
<tr>
<td>37.5 x 37.5</td>
<td>1.27</td>
<td>480</td>
<td>5P</td>
<td>0.60</td>
</tr>
</tbody>
</table>

- Information is based on products currently in production and is subject to change.
- Customer is recommended to contact Freescale for details on specific products.
• Several TBGA packages currently in production, including:
  ▪ 1.27 mm BGA pitch
    > 31 x 31 mm body, 304 TBGA
    > 35 x 35 mm body, 352 TBGA
    > 37.5 x 37.5 mm body, 480 TBGA
  ▪ 1.0 mm BGA pitch
    > 31 x 31 mm body, 500 TBGA
    > 35 x 35 mm body, 672 TBGA
    > 37.5 x 37.5 mm body, 740 TBGA
• Cross-Sectional View of the TBGA:
TBGA Cross-Section near Die Region

- Cu Heat Spreader
- Die Attach
- Die
- Wirebonds (Cut)
- Overmold
- Standoff - Mold to PCB
- Printed Circuit Board

Substrate

40X

500 µm
TBGA Cross-Section of Substrate Layers

Copper Heat Spreader

Adhesive

Tape Substrate

Traces in Tape

Soldermask

Scale: 300X 100 μm
TBGA Advantages

- Increased thermal dissipation
- Excellent board-level reliability
- Very flat / planar over a wide temperature range
- Finer substrate lines and spacing compared to laminate-based wire-bond PBGA substrates
TBGA Thermal Measurements

Four TBGAs evaluated for thermal performance in wind tunnel per JEDEC 51-6

- **352 TBGA**
  - Die Size: 8.74 x 7.32 mm (thermal die)
  - Substrate: 35 x 35 mm

- **480 TBGA**
  - Die Size: 10.16 x 10.16 mm (thermal die)
  - Substrate: 37.5 x 37.5 mm

- **672 TBGA**
  - Die Size: 6.73 x 7.06 mm (thermal die)
  - Substrate: 35 x 35 mm

- **740 TBGA**
  - Die Size: 8.21 x 8.85 mm (thermal die)
  - Substrate: 37.5 x 37.5 mm
Thermal Measurements (cont.)

- Heat Sinks Evaluated
  - “A”: Thermalloy 2330B, 37.9x38.2x16.3 mm, cross cut extrusion pin fin
  - “B”: Thermalloy 2332B, 41.3x43.3x16.3 mm, cross cut extrusion pin fin
  - “C”: Wakefield 698100AB, 53.8x53.1x24.7 mm, cross cut extrusion pin fin

- Note
  - Measurements taken in open flow
  - Heat sinks tested are examples of commercially available heat sinks. Many other heat sinks are available and may be more appropriate for the customer application.
### Thermal Measurements (cont.)

#### No Heat Sink

<table>
<thead>
<tr>
<th>Air Flow (ft/min)</th>
<th>Internal Planes</th>
<th>352 TBGA Theta JA (C/W)</th>
<th>480 TBGA Theta JA (C/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>15.1</td>
<td>13.1</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>12.4</td>
<td>10.7</td>
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<td>200</td>
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<td>9.6</td>
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<td>400</td>
<td>0</td>
<td>9.8</td>
<td>8.2</td>
</tr>
<tr>
<td>800</td>
<td>0</td>
<td>8.0</td>
<td>6.4</td>
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<tr>
<td>800</td>
<td>2</td>
<td>6.8</td>
<td>5.5</td>
</tr>
</tbody>
</table>

#### With Heat Sink

<table>
<thead>
<tr>
<th>Air Flow (ft/min)</th>
<th>Internal Planes</th>
<th>352 TBGA Theta JA (C/W)</th>
<th>480 TBGA Theta JA (C/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
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<tr>
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<td>6.9</td>
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<tr>
<td>400</td>
<td>0</td>
<td>4.3</td>
<td>4.1</td>
</tr>
<tr>
<td>800</td>
<td>0</td>
<td>3.3</td>
<td>3.1</td>
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</tbody>
</table>

Internal planes are the copper layers within the test board. All boards have a top and bottom layer. Ref JESD51-9

Results will vary by die size.
### Thermal Measurements (cont.)

#### No Heat Sink

<table>
<thead>
<tr>
<th>Air flow (ft/min)</th>
<th>Internal Planes</th>
<th>672 TBGA Theta-JA</th>
<th>740 TBGA Theta-JA</th>
<th>672 TBGA Theta-JB (C/W)</th>
<th>740 TBGA Theta-JC (C/W)</th>
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<td>14.4</td>
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<td>1.7</td>
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<tr>
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<td>0</td>
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<td>11.2</td>
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</tr>
<tr>
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<tr>
<td>400</td>
<td>0</td>
<td>4.3</td>
<td>4.2</td>
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<tr>
<td>800</td>
<td>0</td>
<td>3.2</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Internal planes are the copper layers within the test board. All boards have a top and bottom layer. Ref JESD51-9

Results will vary by die size.
Motherboard Pad Design for TBGA

- Motherboard solder pad diameters:
  - In general, motherboard pad solderable diameter should match the package pad diameter
    > See **table on Slide 3** for package pad diameters
  - When required for routing, motherboard pad diameter may be decreased by up to 10% versus the package pad

- Solder pad configurations:
  - Soldermask Defined (SMD) pads:
    > Added strength provided by the soldermask overlap
    > Used on the TBGA package substrate
  - Non-Soldermask Defined (NSMD) pads:
    > Most common type of motherboard pad in the industry
    > Typically results in the most consistent solderability, especially with hot air solder leveled (HASL) surface finish
    > However, may be more likely to fail by pad lifting / trace cracking during bending, high ramp rate thermal cycling or rework
  - NSMD motherboard pads recommended for most applications
1.27 mm Pitch TBGA NSMD Motherboard Solder Pad Geometry

- Recommended non-soldermask defined (NSMD) motherboard pad dimns
  - 0.60 mm solder pad diameter
    > Matches 1.27 mm pitch TBGA pad diameters
  - Surface finish may be any consistently solderable surface such as organic solderability protectant (OSP), HASL, electroless or electrolytic nickel/gold or immersion silver

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- ≥ 0.30 mm (12 mil) Finished Plated Through Hole (Adjustable)
- ≤ 0.65 mm (25 mil) Annular Pad (Adjustable)
- 0.30+ mm (12+ mil) Wide Line Between Pads (For added strength)

- 0.60 ± 0.037 mm (23.6 ± 1.5 mil) Copper Pad Diameter
- 0.075 ± 0.025 mm (3 ± 1 mil) Clearance Between Copper Pad and Soldermask (Adjustable Depending on Supplier Capability)

---

- Soldermask Away From Copper Pad
- PCB Laminate
1.00 mm Pitch TBGA NSMD Motherboard Solder Pad Geometry

- Recommended non-soldermask defined (NSMD) motherboard pad dimensions:
  - 0.45 to 0.50 mm solder pad diameter
    > Should match 1.00 mm pitch TBGA pad diameter
  - Surface finish may be any consistently solderable surface such as organic solderability protectant (OSP), HASL, electroless or electrolytic nickel/gold or immersion silver

- Additional specifications:
  - ≥ 0.30 mm (12 mil) Finished Plated Through Hole (Adjustable)
  - ≤ 0.65 mm (25 mil) Annular Pad (Adjustable)
  - 0.30+ mm (12+ mil) Wide Line Between Pads (For added strength)
  - 0.45 to 0.50 ± 0.037 mm (17.7 to 19.7 ± 1.5 mil) Copper Pad Diameter
  - 0.075 ± 0.025 mm (3 ± 1 mil) Clearance Between Copper Pad and Soldermask (Adjustable Depending on Supplier Capability)
  - Soldermask Away From Copper Pad
  - PCB Laminate
  - Solder Pad
Surface Mount Assembly of TBGA

- No minimum solder paste volume is typically required since the solder ball melts during reflow.
- TBGA can have a high thermal mass relative to other components and should be carefully profiled with a thermocouple in a corner and inner sphere on a fully populated profile PCB.
- SnPb TBGA qualified to a maximum reflow temperature of 220°C and Pb-free TBGA is qualified to 260°C.
- Soldering profiles are solder paste dependent, but here are some guidelines that can be used:
  - **SnPb soldering:**
    - Raise temperature of the joints to 100°C at between 1.5 and 3.0°C/sec.
    - Peak component temperature typically between 205 and 220°C.
    - Desirable dwell time above 183°C between 50 and 80 secs.
  - **Pb-free soldering:**
    - Raise temperature of the joints to 100°C at between 1.5 and 3.0°C/sec.
    - Peak component temperature typically between 235 and 245°C.
    - Desirable dwell time above 217°C between 50 and 80 secs.
TBGA CTE Analysis

• Composite CTE measurements have been taken on 352 35mm x 35mm TBGA using Moiré Analysis
  ▪ Backside (Cu heat spreader): 17.5 ppm/°C
  ▪ Frontside (BGA and cavity side): 17.2-18.0 ppm/°C
• Package well matched to most epoxy/glass motherboards which have a CTE of 16 to 22 ppm/°C resulting in outstanding board level reliability
740 TBGA Weibull Plot of ATC – Board Level Reliability

(Also tested was 0/100C cycling of both alloys and they reached in excess of 6000 cycles before failure distributions started. 0/100C, 10 minute ramps and dwells.)

Daisy Chain packages used for test. Continuous in-situ resistance monitoring.

Number of Air Temperature Cycles (-40/125C)

<table>
<thead>
<tr>
<th>Eta</th>
<th>Beta</th>
<th>r^2</th>
<th>n/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>3441</td>
<td>6.257</td>
<td>0.948</td>
<td>20/3</td>
</tr>
<tr>
<td>2754</td>
<td>22.11</td>
<td>0.689</td>
<td>10/2</td>
</tr>
</tbody>
</table>
Bend Test

Connections to monitor daisy chain net

Daisy chain package mounted to PCB

Strain gage 1 cm from part edge, global strain value

Unpopulated package site

4 point bend anvils centered to package

IPC-9702 used for test and PCB design.
740 TBGA Weibull Plot of Break Strain – Bend Test

740 TBGA IPC-9702 Monotonic Bend Test
37.5x37.5 mm sq., 1.0 mm Pitch, Varied Solder Alloy

![Graph showing strain at open (microstrain)](image)

<table>
<thead>
<tr>
<th>Eta</th>
<th>Beta</th>
<th>r^2</th>
<th>n/s</th>
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<tr>
<td>5115</td>
<td>6.738</td>
<td>0.977</td>
<td>12/0</td>
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<tr>
<td>4340</td>
<td>10.15</td>
<td>0.979</td>
<td>15/0</td>
</tr>
</tbody>
</table>
480 37.5 x 37.5 TBGA Board-Mounted Solder Joint Stand-Off

Notes:
- Package very flat with 0.05 mm (2.0 mil) variation across entire 37.5 mm package.
- Overall mean stand-off height is 0.507 mm (20.0 mils).
- 0.15 mm thick solder paste stencil with 0.58 mm apertures.
- 0.635 mm SMD package pads.
- 0.58 mm NSMD test board pads.
- OSP surface finish on test boards.
### TherMoiré Warpage (um) at Temperature Read Points

<table>
<thead>
<tr>
<th>Profile</th>
<th>Heating</th>
<th>Peak</th>
<th>Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>30°C</td>
<td>90°C</td>
<td>151°C</td>
</tr>
<tr>
<td>Sample 1</td>
<td>43</td>
<td>45</td>
<td>44</td>
</tr>
<tr>
<td>Sample 2</td>
<td>46</td>
<td>42</td>
<td>44</td>
</tr>
<tr>
<td>Sample 3</td>
<td>56</td>
<td>46</td>
<td>44</td>
</tr>
<tr>
<td>Minimum</td>
<td>43</td>
<td>42</td>
<td>40</td>
</tr>
<tr>
<td>Maximum</td>
<td>56</td>
<td>46</td>
<td>45</td>
</tr>
<tr>
<td>Average</td>
<td>48.3</td>
<td>44.3</td>
<td>43.0</td>
</tr>
</tbody>
</table>

#### 37.5 x 37.5 480 TBGA TherMoiré

- **Peak temperature is 247°C**
- **Data was taken from the sphere side of the package**
- **Samples were baked, spheres removed, and painted prior to TherMoiré**
- **The mold cap in the center was masked out for a more accurate measurement**
TherMoiré Of 480 TBGA Bottom with Spheres Removed
Sample # 1 - Heating

Mold cap area masked out

30°C

90°C

151°C

183°C

A1 Corner

35
31
28
24
21
17
14
10
7
3
-1
-4
-8
-11
-15
-18
-22

Cleplanarity = 40 microns

Cleplanarity = 45 microns

Cleplanarity = 42 microns

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TherMoiré Of 480 TBGA Bottom with Spheres Removed
Sample # 1 - Heating

195°C

220°C

247°C

220°C

A1 Corner

Coplanarity ~ 41 microns

Coplanarity ~ 39 microns

Coplanarity ~ 40 microns

Coplanarity ~ 44 microns
TherMoiré Of 480 TBGA Bottom with Spheres Removed Sample # 1 - Cooling

195°C

A1 Corner

181°C

150°C

35

31

28

24

21

17

14

10

7

3

-1

-4

-8

-11

-15

-18

-22

Coplanarity = 41 microns

Coplanarity = 44 microns

Coplanarity = 46 microns

90°C

30°C

Coplanarity = 50 microns

Coplanarity = 48 microns
TherMoiré Of 480 TBGA Bottom with Spheres Removed
Sample # 2 - Heating

30°C

A1 Corner

90°C

151°C

183°C

Cepheusity ~ 47 microns

Cepheusity ~ 40 microns

Cepheusity ~ 40 microns

Cepheusity ~ 47 microns
TherMoiré Of 480 TBGA Bottom with Spheres Removed
Sample # 2 - Heating

195°C

220°C

247°C

220°C

A1 Corner
TherMoiré Of 480 TBGA Bottom with Spheres Removed
Sample # 3 - Heating
TherMoiré Of 480 TBGA Bottom with Spheres Removed
Sample # 3 - Heating

195°C
220°C

247°C
220°C

A1 Corner

Coplanarity = 44 microns
Coplanarity = 45 microns
Coplanarity = 50 microns
Coplanarity = 49 microns
TherMoiré of 480 TBGA Bottom with Spheres Removed
Sample #3 - Cooling

A1 Corner

195°C

181°C

150°C

90°C

30°C

Coplanarity = 47 microns

Coplanarity = 46 microns

Coplanarity = 40 microns

Coplanarity = 40 microns

Coplanarity = 40 microns

Coplanarity = 40 microns
• 740 pin TBGA
  - Weight gain in 338 hours of 30°C/60%RH soak
  - Weight loss in 125°C bake-out
  - Industry standard 24 hour bake

Note: FSL recommends to bake parts for 24 hours at 125degC.