PCB DESIGN PERFECTION: THE CAD LIBRARY SERIES PART 3: BGA (BALL GRID ARRAYS)

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ABSTRACT

This paper, the third in a series dedicated to CAD library quality, describes each aspect to consider when creating BGA (Ball Grid Array) component library parts. It also describes the impact each feature has in the PCB process.

WHITEPAPER

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P A D S

THE UNITS

Today, 90% of all component manufacturers list their component package dimensions in metric units. Accordingly, this paper utilizes metric units for CAD library development.

BGA COMPONENTS:

The BGA started out with a pin pitch of 1.5 mm but was quickly reduced to 1.27 mm (50 mils), where it remained for about 15 years. In the late 1990's, the 1 mm pitch BGA was introduced and since then a smaller pin pitch has been introduced every couple of years. Today 0.4 mm pitch BGA's are common and can be found in small consumer products like cell phones. The next generation of BGA's will be even smaller. See Figure 1.

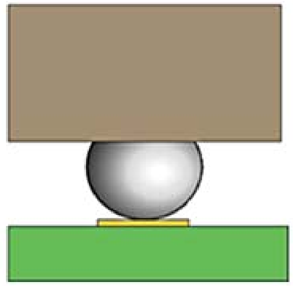

Figure 1: BGA Lead Example

THE TWO TYPES OF BGA BALL LEADS

TYPE 1 - NON-COLLAPSING

Non-collapsing BGA's normally have a pitch of 0.5 mm or smaller, where the Land (pad) is larger than the ball to allow for via-in-pad technology and to provide an adequate annular ring. The solder mask can be the same size as the Land. In some cases - the Land for fine pitch BGA's is solder mask defined - where the solder mask encroaches slightly over the land. This provides protection for any trace routing between the lands but the most significant benefit is to help secure the Land to the PCB.

During cell phone "drop testing", the BGA solder joint normally holds better than the land to the prepreg. (i.e.: drop tests prove that the non-solder mask land will rip from the PCB before the solder joint breaks.) So the solder mask defined land is secured better to the PCB for drop testing. See Figure 2 for side-by-side examples of non-collapsing and collapsing BGA balls.

TYPE 2 - COLLAPSING

Collapsing BGA's normally have a pitch of 0.65 mm and higher, where the Land (pad) is smaller than the Ball size to allow the Ball to collapse around the sides of the Land. This requires a non-solder mask defined Land where the solder mask must be larger than the Land. See Figure 2 for side-by-side examples of non-collapsing and collapsing BGA balls.

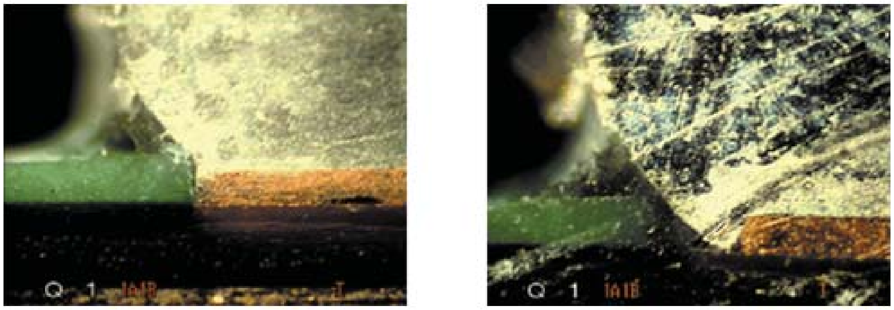

Figure 2: Non-collapsing BGA ball - Left. Collapsing BGA Ball – Right

COLLAPSING BGA LAND (PAD) SIZES

The Land (pad) size for collapsing BGA's is determined by the ball size in accordance with the IPC-7351B land pattern standard as seen below in Table 1. Notice the correlation between the "reduction" and the "land pattern density level". The three density levels change the land size reduction percentage, but they also determine the Placement Courtyard Excess. See Table 3.

Mentor Graphics' xDM Land Pattern Creator utilizes the calculations shown in Table 1 as described in IPC 7351B for collapsible solder balls, but it is very important to note that IPC prefers the Maximum Material Condition for all BGA Land sizes; they do not use the Nominal Land Diameter, but do use the Maximum Land Variation Diameter (as shown in bold font in the "Land Variation" column).

The standard BGA ball sizes listed in Table 1 are in 0.05 mm increments until the pin pitch hits 0.5 mm and less. Though industry standards try to keep BGA balls sizes in 0.05 mm increments, component manufacturers sometimes do not adhere to the standard and create BGA ball sizes in 0.01 mm increments. The BGA pin pitches are also in 0.05 mm increments. As a result, the BGA land (pad) sizes are in 0.05 mm increments including the via fanout padstacks and hole sizes.

Nominal Ball Diameter	Reduction	Land Pattern Density Level	Nominal Land Diameter	Land Variation
0.75	25%	A	0.55	**0.60** - 0.50
0.65	25%	A	0.50	**0.55** - 0.45
0.60	25%	A	0.45	**0.50** - 0.40
0.55	25%	A	0.40	**0.45** - 0.35
0.50	20%	B	0.40	**0.45** - 0.35
0.45	20%	B	0.35	**0.40** - 0.30
0.40	20%	B	0.30	**0.35** - 0.25
0.35	20%	B	0.30	**0.35** - 0.25
0.30	20%	B	0.25	**0.25** - 0.20
0.25	20%	B	0.20	**0.20** - 0.17
0.20	15%	C	0.17	**0.20** - 0.14
0.17	15%	C	0.15	**0.18** - 0.12
0.15	15%	C	0.13	**0.15** - 0.10

Table 1: Land Approximation for Collapsible Solder Balls

IPC-7351B has a three-tier BGA formula for Placement Courtyard Excess that uses the BGA ball size to calculate an adequate placement courtyard for BGA rework tools. If the BGA has a large ball size, larger rework equipment is necessary to unsolder the increased solder volume.

With a small ball size, the placement courtyard can be smaller as less heat is required to unsolder the BGA component for rework. However, the end user may not plan to rework the BGA if it fails. In that case, there is no need to have a robust placement courtyard. The recommended minimum placement courtyard excess is 0.5 mm.

NON-COLLAPSING BGA LAND SIZES

The Land (pad) size for non- collapsing BGA's is determined by the ball size as seen below in Table 2 in accordance with the IPC-7351B land pattern standard. It is important to note that IPC prefers the Maximum Material Condition for all BGA Land Sizes, meaning that the Maximum Land Variation Diameter is used; not the "Nominal Land Diameter".

Non-Collapsing 0.5 mm Pitch BGA for Lead-Free and Via-in-Pad Example

Figure 3 is a 0.5 pitch non-collapsing BGA ball. Instead of shrinking, the non-collapsing land size gets larger to handle the solder volume that creates the solder joint. This technology is new to the electronics industry and was created as a solution for lead-free BGA balls and via-in-pad technology to support routing with fine pitch BGA components.

Nominal Ball Diameter	Increase	Nominal Land Diameter	Land Variation
0.75	15%	0.85	0.90 - 0.80
0.65	15%	0.75	0.80 - 0.70
0.60	15%	0.70	0.75 - 0.65
0.55	15%	0.65	0.70 - 0.60
0.50	10%	0.55	0.60 - 0.50
0.45	10%	0.50	0.55 - 0.45
0.40	10%	0.45	0.50 - 0.40
0.35	10%	0.40	0.45 - 0.35
0.30	10%	0.35	0.40 - 0.30
0.25	10%	0.30	0.35 - 0.25
0.20	5%	0.21	0.26 - 0.16
0.17	5%	0.18	0.22 - 0.13
0.15	5%	0.16	0.21 - 0.11

Table 2: Non-Collapsing BGA Land Calculations

BGA

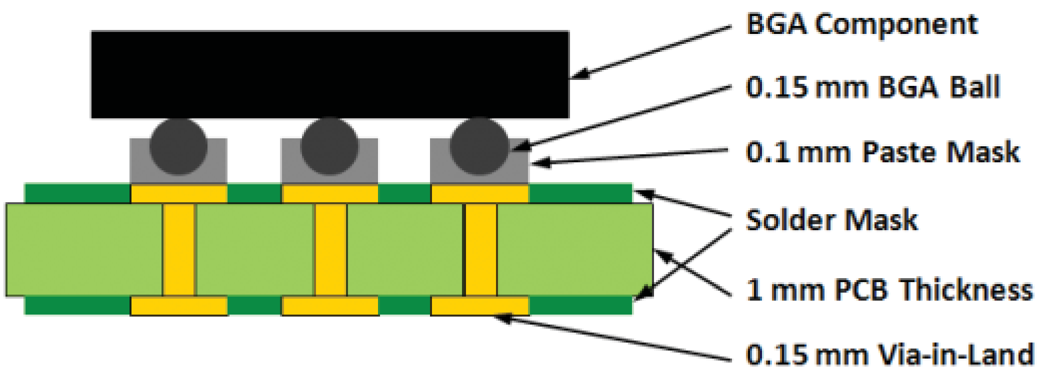

Figure 3: Non-Collapsing 0.5 mm Pitch BGA

Via-in-Land Technology
BGA Ball Size: 0.15
BGA Land Dia: 0.275
Hole Size: 0.15
Thermal Relief Required
Plane Clearance: 0.425
Solder Mask: 1:1 scale

Trace/Space & Grid Data
Trace Width: 0.075
Trace/Trace Space: 0.075
Trace/Via Space: 0.075
Trace/BGA Land: 0.075
Routing Grid: 0.05
Part Place Grid: 1

PLACEMENT COURTYARD

IPC-7351A has a three-tier BGA formula for Placement Courtyards that uses the BGA ball size to calculate an adequate placement courtyard for BGA rework tools. If the BGA has a large ball size, larger rework equipment is necessary to unsolder the large solder volume. With a small ball size, the placement courtyard can be smaller as less heat is then required to unsolder the BGA component for rework. However, the end user may not plan to rework the BGA if it fails. In that case, there is no need to have a robust placement courtyard. The three-tier placement courtyard excess sizes based on BGA density are provided in Table 3.

Lead Part	Most Density Level A	Nominal Density Level B	Least Density Level C
Collapsing Ball	25% Reduction	20% Reduction	15% Reduction
Non-collapsing Ball	15% Reduction	10% Reduction	5% Reduction
Courtyard Excess	**2.00**	**1.00**	**0.50**
Round-off Factor	Round off to the nearest two place 0.05 decimal, i.e.: 1.00, 1.05, 1.10, 1.15		

Table 3: BGA Density Levels for Placement Courtyard Size Determination

CONCLUSION

When creating BGA components, every aspect of the design should be considered including the impact that each land pattern feature has in the PCB design process. The land pattern is the starting point that affects every process from PCB layout through PCB manufacturing and assembly. There are dozens of things to consider when creating a CAD library that are often overlooked; this paper discussed the factors to consider when creating molded body component library parts. Each factor can directly affect the quality of the part placement, via fanout, trace routing, post processing, and fabrication and assembly processes.

DID YOU KNOW?

PADS, Mentor Graphics' Personal Automated Design System, includes everything you need in order to create your component library. PADS provides a highly integrated library and component management environment that meets designers' and engineers' needs in creating and maintaining PCB design libraries.

PADS LIBRARY MANAGEMENT COMBINES:

- A starter library containing more than 10,000 ready-to-use, IPC-compliant, proven parts provided by Optimum Design Associates for a quick start to new design projects.
- Web access to component supplier data with an ability to load contents into PADS
- A central library for maintaining up-to-date design data. The central library contains all library elements in the same location, and is available at all design stages. PADS makes it possible to maintain an up-to-date library in real time, without any compilation, and includes all library elements (e.g., symbols, part data, footprints, simulation models, drawing items, and part common-property definitions).
- A component management system, integrated with schematic design and library management environments.
- A built-in consistency check of library data to make sure your library is constantly in-sync.
- Live verification of symbols placed in your schematic against the latest component and library data to eliminate costly redesigns and quality problems that might otherwise go undetected until late in the design cycle.
- A land pattern creator for quick creation of IPC-standard footprints.
- A migration path for 3rd-party libraries and component databases.

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