Chapter E: BGA

Ball Grid Array (BGA) Technology

The information presented in this chapter has been collected from a number of sources describing BGA activities, both nationally at IVF and reported elsewhere in the literature, the most important of the former being the Swedish National Research Programme ”BGA Modules for Automotive Electronics in Harsh Environments”, funded by NUTEK and carried out between 1994 and 1997.

1. Overview of the BGA Technology

The present miniaturization trend towards higher-performance, smaller and lighter products has resulted in an increasing demand for smaller component packages and/or higher pin counts. The Quad Flat Pack (QFP) and the Ball Grid Array (BGA) packages today both offer a large number of I/Os, as required by modern IC technology. The BGA concept has received much appreciation owing to its inherent, potential benefits to surface mount production. In order to accommodate the increasing number of I/Os needed, the peripheral QFP technology is forced to an ever finer lead pitch with thinner and more fragile leads. The BGA, taking advantage of the area under the package for the solder sphere interconnections, satisfies the I/O demand using a far coarser pitch. Additionally, the package size and the board real estate required are usually smaller for BGA packages. For cost reasons, however, only plastic BGAs will probably be an alternative for most consumer applications. The leadless feature of the BGA package raises some doubts about the reliability in harsh environments and in applications where large temperature variations are encountered

The relationship between BGA and QFP packages' size and I/O count is illustrated in Figure 1. A typical 0.65 mm (25.6 mil) fine-pitch QFP with 160 leads measures 28x28 mm. Modern portable electronics asking for the same number of leads in a package 14x14 mm ends up at 0.3 mm (11.8 mil) pitch with a space between the leads of only 0.15 mm (6 mils). Alternatively, increasing the number of I/Os while retaining the 0.65 mm pitch, means e.g. 232 leads in a 40x40 mm body. A 27x27 mm plastic BGA (PBGA) houses 225 I/Os with a coarse 1.5 mm pitch. The distance between adjacent solder spheres is approximately 0.8 mm. The more I/Os needed, the better off with the BGA in terms of package size since the dimensions only grow as the square root of the I/O count for a given pitch, and not linearly as is the case for QFPs.

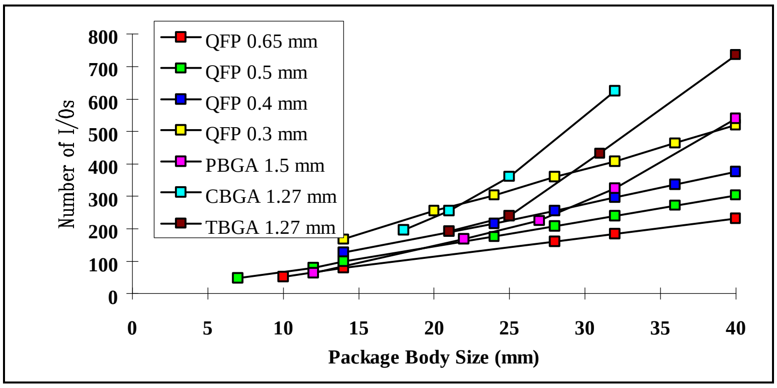

Figure 1. Size comparison of square QFP and BGA packages of different types and with different I/O's.

1.1 Introduction to BGA Technology

A BGA package can typically be characterized by the following three general statements:

- It is an IC package for active devices intended for surface mount applications
- It is an area array package, i.e. utilizing whole or part of the device footprint for interconnections

- The interconnections are made of balls (spheres) of most often a solder alloy or sometimes other metals

More specifically, the BGA package usually fulfils the following additional requirements:

- The length of the package body (most often square) ranges from 7 to 50 mm
- Lead counts over 1000 possible, but 50 to 500 range most common today
- The pitch, i.e center-to-center distance, of the balls is generally between 1.0 and 1.5 mm

Figure 2 below illustrates the difference between QFP and BGA packages, showing an ultra fine-pitch 160 lead QFP (pitch 0.3 mm) on a background consisting of the bottom side of a 1.5 mm pitch PBGA with 225 interconnection solder balls. From this picture it is easy to understand the popularity this BGA package has received among the people in the assembly business. Note that there are five QFP leads for every BGA solder sphere.

Figure 2. A 160-lead 0.3 mm (11.8 mil) pitch QFP placed on a grid of 1.5 mm pitch spheres (bottom side of a PBGAS225).

1.1.1 BGA History

Motorola and Citizen jointly developed the plastic BGA (PBGA) in 1989, following a very similar approach used by Motorola and IBM for a number of years with the ceramic BGA (CBGA). Wide spread use of PBGAs was seen in the mid nineties by e.g. Compag Computers and Motorola. Since the introduction of the OMPAC (Over Molded Pad Array Carrier), as the PBGA first was named, there has been a tremendous number of new versions or slight alterations to the original BGA ideas by the very many players on the market. This chapter will only be able to mention but a few of the now existing BGA package types, with main emphasis on the PBGA as it is believed to be of most importance Some comparisons will also be made with conventional quad flat packs (QFPs) and CBGAs and other types of BGA packages such as the TBGA (Tape BGA) or the SBGA (Super BGA), recently presented. Also outside the scope of this text is the multichip moudule - or MCM-BGAs, which are similar in construction to ordinary BGAs, but contain two or more chips inside the package.

1.1.2 Common BGA packages

The most popular and perhaps the most interesting package to study from a cost point-of-view is the plastic package, PBGA, though it should be recognised that it only represents one path in the tree of possible BGA package alternatives., as can be seen in Figure 3. The plastic PBGA catgory can be further divided into groups related to the package construction, the chip being being either over molded, glob topped or sealed with a plastic lid. Furthermore, the chip inside the BGA package may be either wirebonded or flip chip attached to the substrate. However, from the BGA user’s point-of-view, these subtle differences may be of less importance.

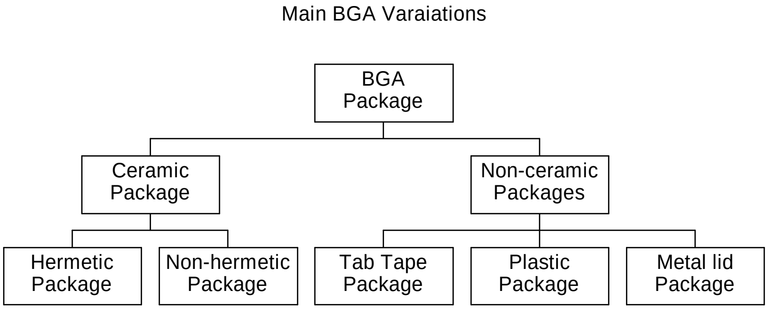

Figure 3. The main variations of Ball Grid Array packages.

A cross-section of an OMPAC PBGA is shown in Figure 4, depicting the over-molded and wire-bonded chip, attached to the BT carrier (sometimes FR-4) substrate, the other side of which is attached to the solder balls responsible for the final interconnection to the printed circuit board. The substate is generally is made of 0.25 mm thick BT (bismaleimide-triazine) epoxy glass laminate with 18 µm copper thickness. For lower pin counts, most often a two sided substrate metallization is sufficient to provide electrical contact from wire-bonds through plated through-holes to solder ball pads. In addition, thermal balls under the center of the package are often used to remove heat from the device through thermal vias.

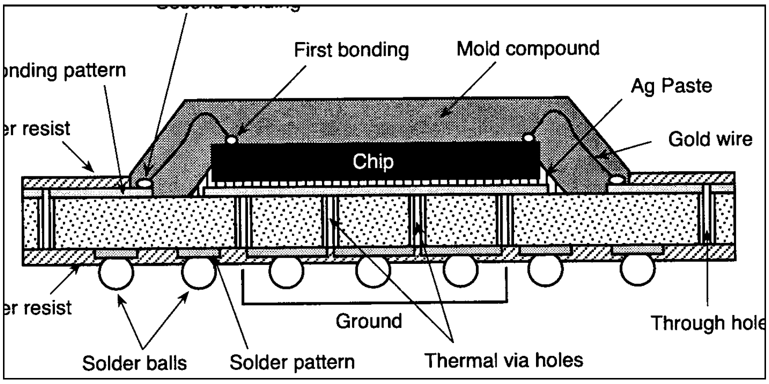

Figure 4. A cross-section of a typical OMPAC PBGA.

Another interesting, but not yet so common type of BGA package, is the Tape or Tab BGA, hence TBGA. This type is based on a flexible polyimide film (tape) with copper metallization on both sides. Solder attachment balls of high temperature 10Sn90Pb alloy are used. Since one side of the PI film serves as aground plane, good low-noise electrical performance is achieved. The PI film is generally 50 µm tkick and the diameter of the solder balls is usually 0.63 mm for a package pitch of 1.27 mm. The back of the chip can be put in direct contact with a thermally conductive adhesive to provide efficient transport of heat to the metal cover or heatsink, see Figure 5 below. This construction allows a higher degree of power dissipation than feasible using plastic packages.

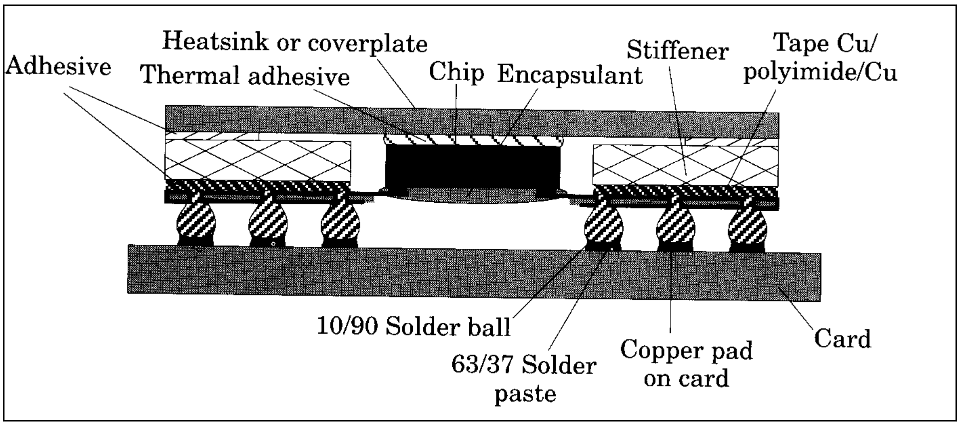

Figure 5. A cross-section of a Tape (or TAB) BGA - TBGA.

A similar, but yet different approach can be found in the Super BGA or SBGA package which also gives improved electrical and thermal performance over the standard PBGAs. Like the TBGA, it uses a metal heatsink plate attached to the back side of the chip to provide power dissipation as well as serving as stiffener and ground plane. Unlike the TBGA, the chip is generally wire bonded inside the SBGA package, see Figure 6 below.

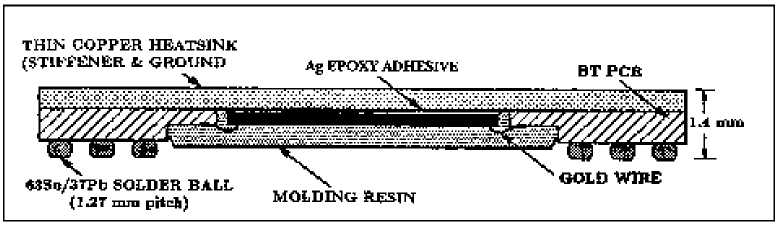

Figure 6. A cross-section of a Super BGA - SBGA.

1.1.3 Driving Forces for using BGAs

Replacing QFPs with BGAs not only means that higher pin counts or smaller packages can be achieved, but also that a considerably higher manufacturing process yield can be reached. Today, the manufacturing aspects seem to be the major driving forces for the BGA technology, although issues like cost, reliability, and rework and inspection will probably soon push the technology further. Even though a choice between the BGA and QFP technologies seems easy from a production point of view, the alternatives still have to be considered and all pertinent issues should be carefully addressed.
To summarize, the driving forces can be listed (not in order of importance) as:

- Savings in the printed circuit board area required per function
- Potential for higher assembly yields
- Increased electrical performance
- Possibility for higher power dissipation devices
- Lower overall production costs
- Reliability constraints in specific applications

1.1.4 Advantages and disadvantages using BGAs

As a consequence of the BGA packaging technology, there are a few issues that automatically come along and have to be specifically identified and examined before the technology is fully adopted. Among the pros and cons of the technology, we can summarize the following, sometimes critical, issues:

Advantages

- In general, BGAs have better electrical properties than their QFP counterparts

- BGAs are less fragile and easier to handle both before and during assembly
- The placement operation is usually far easier and more reliable than for fine-pitch QFPs
- A much higher assembly yield is generally expected using BGAs
- The smaller package size or the higher I/O count allows a further step in miniaturization

Disadvantages

- There are problems and costs associated with PCB routing, especially for full matrix packages
- BGAs are more sensitive to moisture uptake and more prone to give pop corning effects
- Inspection of the solder joints is impossible without costly x-ray equipment
- BGA packages may have coplanarity problems, particularly for larger devices
- Reliability not yet proven due to many design and assembly parameters still being changed
- Board level rework potentially more difficult

1.1.5 Standards and Common Practice

The most comprehensive source of information, but maybe not the easiest to grasp, is the Joint Industry Standard J-STD-013 available from the IPC, The institute for Interconnecting and Packaging Electronics Circuits, Northbrook, IL, USA. The document, entitled ”Implementation of Ball Grid Array and Other High Density Technology”, establishes the requirements and interactions necessary for printed board assembly processes for BGA packages. Included is information on design principles, material selection, board fabrication, assembly technology, testing strategy and reliability expectations based on end-use environments.

New standards that need to be created are defined in J-STD-013, published in 1996. These standards, some of which are already being dealt with, include the following:

- Std No. 201: Design Standard for Ball Grid Array Applications
- Std No. 202: Performance Standard for Ball Grid Array Bumps & Columns
- Std No. 207: Design Standard for Ball Grid Array/Hi-Density Mounting Structures
- Std No. 208: Qualification and Performance Standard for Ball Grid Array Organic Mounting Structures
- Std No. 209: Qualification and Performance Standard for Ball Grid Array Inorganic Mounting Structures
- Std No. 210: Test Methods for Qualification and Evaluation of Ball Grid Array Mounting Structures
- Std No. 211: Design Standard for Ball Grid Array and Hi-Density Package Assembly Configuration
- Std No. 212: Standard for Ball Grid Array Assembly Performance Requirements
- Std No. 213: Test Methods for Qualification and Evaluation of Ball Grid Array Assemblies
- Std No. 214: Standard for Ball Grid Array Assembly Rework and Repair Techniques
- Std No. 216: Qualification and Performance Standard for Flux used in Ball Grid Array Assembly

1.1.6 Price versus Performance

Still at this time, even the cheapest plastic BGAs are generally slightly more expensive than their QFP counterparts, especially for I/O numbers below 250 or so. This cost increase at package level may turn into a overall cost decrease at board level owing to potential higher assembly yields. However, BGA packages involving carrier substrates with more than two layers are not likely to compete with QFP costs at lower pin counts. The reason for the higher cost of the PBGAs are to be found in mainly materials costs of the high-temperature BT epoxy substrate