The Nordic Electronic Packaging Guideline

Chapter E: BGA

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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.

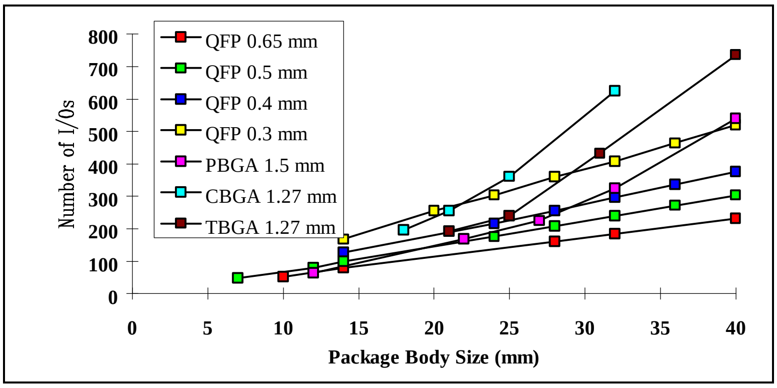

Figure 1. Size comparison of square QFP and BGA packages of different types and with different I/O's.

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.

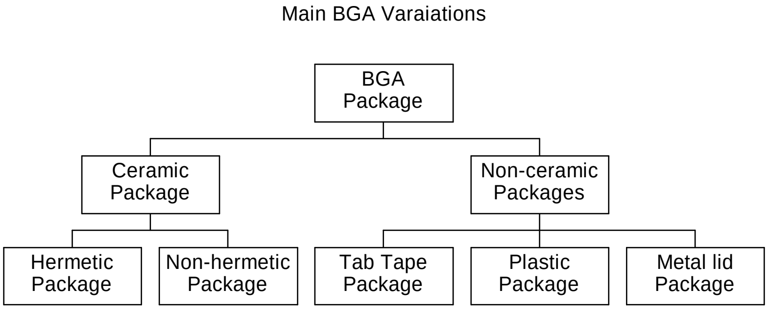

Figure 3. The main variations of Ball Grid Array packages.

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.

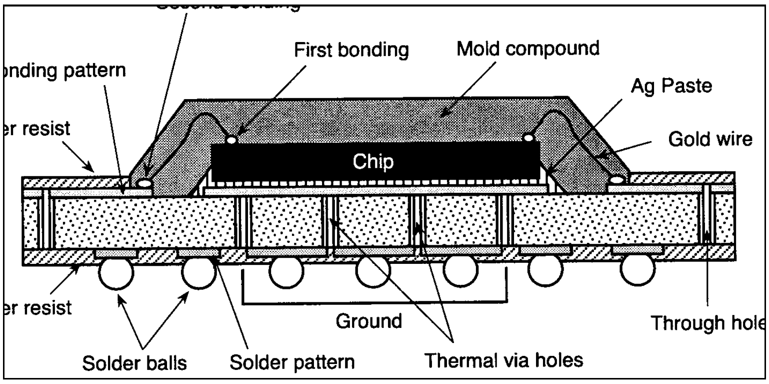

Figure 4. A cross-section of a typical OMPAC PBGA.

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.

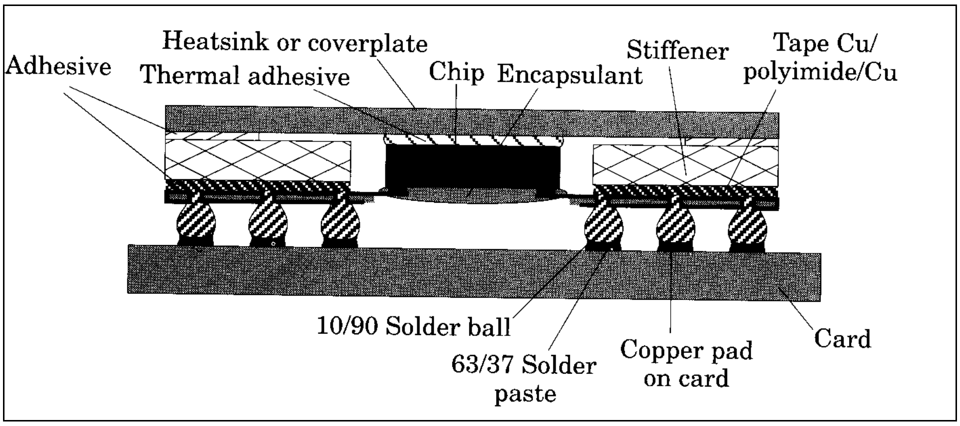

Figure 5. A cross-section of a Tape (or TAB) BGA - TBGA.

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.

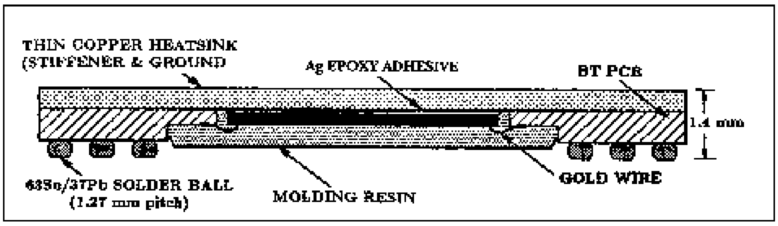

Figure 6. A cross-section of a Super BGA - SBGA.

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 and the costs of the fine line circuitry technology required.

Chapter E: BGA

2. Conclusions and Guidelines

2.1 Technical Issues

2.1.1 Basic properties of BGA packages

The following table summarizes some key features comparing a conventional PGA package (pin grid array), to plastic QFP and BGA and TBGAs (Hwang p14).

Table 1. Typical key features of various packages (adopted from Hwang).

Feature	PGA	QFP	BGA	TBGA
Lead count	208	208	225	224
Pitch (mm)	2.5	0.5	1.27	1.27
Foot print (mm2)	1140	785	670	530
Ratio of package to die	11	8	7	5
Inductance (nH)	5	6	4	3
Capacitance (pF)	7	0.5	1	1.5
Thermal resistance (°C/W)	2.5	0.5	10	1.5

2.1.2 Electrical performance

Low noise is achieved with TBGA and SBGA packages owing to ground planes incorporated into the structures. The SBGA is reported of being capable of performing at very high speeds (2 GHz) (Lau p48). With the basic PBGA, however, the most natural design for economical reasons is probably the worst package for electrical performance (Lau p351), and the standard OMPAC needs to be electrically enhanced if it is to be used in high-frequency applications, i.e. above some 50 MHz.. The conductors are essentially doubling over on themselves, separated only by the thickness of the substrate. This results in a very high mutual- and self inductance of the substrate, generally higher than of QFPs of comparable lead counts. Even so, the standard OMPAC design is most often adequate for general and moderate devices and applications. The main advantage using the PBGA, is of course the shorter and more widely spaced interconnects (solder spheres) giving an electrical connection of significantly lower inductance than traditional packages. Additionally, most high-performance PBGAs have greater potential to system performance increase than other package types mainly because of the smaller size and thus shorter conductor paths required.

Table 2 below is a comparison of typical PACKAGE features and related electrical parameters of a plastic BGA and a plastic QFP. The three electrical parameters capacitance, inductance, and resistance, are inherently found in every packaging concept. The resistance may cause signal line DC drops while contributing to charging delays in RC networks. On the other hand, the resistance may also reduce undesired noise at a system level. The capacitance is mainly responsible for signal delays and can be reduced by reducing the physical dimensions of the RC networks. The inductance also contributes to the switching noise and delays associated with the packages. A low dielectric constant is favourable both for signal delay and crosstalk, which is the coupled noise from busy signal paths to idle paths caused by mutual capacitive and inductive coupling. A typical value of the dielectric constant (ε_r) for plastic BGA substrates is in the range 3.5 to 5.

Table 2. Typical package features and electrical parameters comparing two plastic packages (After Lau p.371)

Attribute	PQFP208	PBGA225
Lead count	208	225
Pitch (mm)	0.5	1.5
Size (mm)	31x31	27x27
Shortest/longest signal path(mm)	10.2/13.7	6.8/22.5
Smallest Inductance (nH)	6.3-7.1	3.3-5.8

Largest Inductance (nH)	8.9-9.8	10-11.2
Inductive coupling (K_L)	0.68-0.70	0.12-0.25
Capacitance (pF)	1.61-2.38	1.28-1.31
Signal propagation delay (ps)	9-14.5	5-9.1
Switching (ΔI) noise (mV)	730	550
Crosstalk (mV)	510	90
Direct current resistance (mΩ)	70-80	20-24

2.1.3 Thermal performance (heat dissipation and cooling techniques)

A common perception about the BGA packaging concept is that it is superior to both QFP and PGA in terms of thermal performance. However, plastic BGA are not very different from plastic QFP or PGA packages, a slightly improved response may be seen owing to the overall shorter thermal paths associated with a BGA package. The thermal conductivity of a PBGA BT substrate is typically on the order of 0.2 W/m°C which is approximately ten times lower than that of the silver filled die attach adhesive used to bond the back of the chip to the substrate die pad. Plastic packages, especially the OMPAC type, suffers substantially in this respect from the overmould compound being very thick, up to 1 mm, further aggravated by a thermal resistance value of around 0.7 W/m°C . There are a number of heatsinks available to attach to the BGA package body, increasing the cooling capabilities. However, reliability studies involving PBGAs have shown that the heatsink itself may have a negative effect on the solder joint reliability because of the mechanically induced stress associated with the use of heatsinks (Mawer 1997).

2.1.4 Reliability issues

This section addresses reliability aspects of great importance to any user of BGA packages. Results from reliability tests, performed at IVF, under harsh automotive-like environmental conditions are presented, involving different BGA packages, including OMPACS, Super BGAs and Tape BGAs, as well as fine-pitch quad flatpacks serving as a reference. All packages were mounted to standard gold-plated FR-4 test boards, specifically designed for the tests. Daisy Chain packages were used to check the electrical performance of the solder joints. The environmental tests comprised temperature cycling from -40 to 100°C, with and without simultaneous exposure to vibration (8 G, 10-500 Hz) during the high temperature phase.

The results show that non-soldermask defined (NSMD) pads on both board and package give superior performance for the PBGA361, compared to when solder mask defined (SMD) pads are used. The 1.27 mm pitch PBGA361 passed 5000 cycles and the PBGA256, as well as the QFP reference samples, passed 6000 cycles from -40 to 100 °C without failure. Cross-section analysis after 6000 thermal cycles, performed on 1.5 mm pitch PBGA225s, shows extensive cracking, which however could be avoided with the use of a suitable underfill.

Results from measurements of intermittent failures during temperature cycling of the 1.27 mm pitch PBGA361s, recorded by a high-speed event detector, are shown in Figure 7 below.

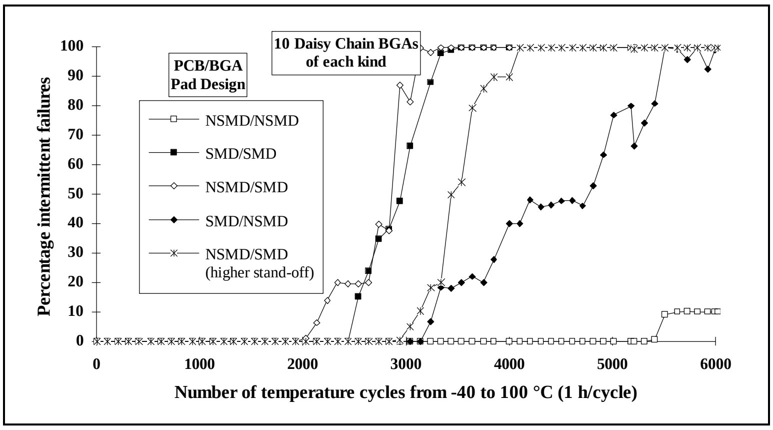

Figure 7. Pad design influence on reliability of 1.27 mm pitch PBGA361 during temperature cycling.

As evident from Figure 4, the most important factor for achieving high reliability is to have an NSMD pad on the BGA package substrate. The use of NSMD pads on both the board and the BGA package did not yield any intermittent failures up to 5500 cycles (1 hour per cycle), while switching to SMD pads on the board caused failures to start at approximately 3000 cycles. However, if NSMD BGA packages are not available, it is not recommended to use NSMD pads only on the board, as this combination (NSMD/SMD) gives an even shorter life than SMD pads on both sides. The reason for the lower reliability with the NSMD/SMD combination is assumed to be a stress concentration to a weaker point at the package-ball interface. The stand-off is approximately the same in the two cases NSMD/SMD and SMD/NSMD and therefore cannot explain the different failure behaviour. However, it is clear from the diagram that an increased stand-off for the NSMD/SMD combination actually delays the onset of intermittent failures to a value slightly better than SMD/SMD.

The location of the open joints in the PBGA361 Daisy Chain packages, was found by manually probing the packages that had shown intermittent failures during temperature cycling, mainly packages with SMD pad designs. The result is depicted in Figure 8 below, which with remarkable consistency shows that electrical integrity is lost predominantly in joints near the die edge. Each black dot in Figure 8 denotes an open circuit in either or both of the two joints forming that particular pair of joints.

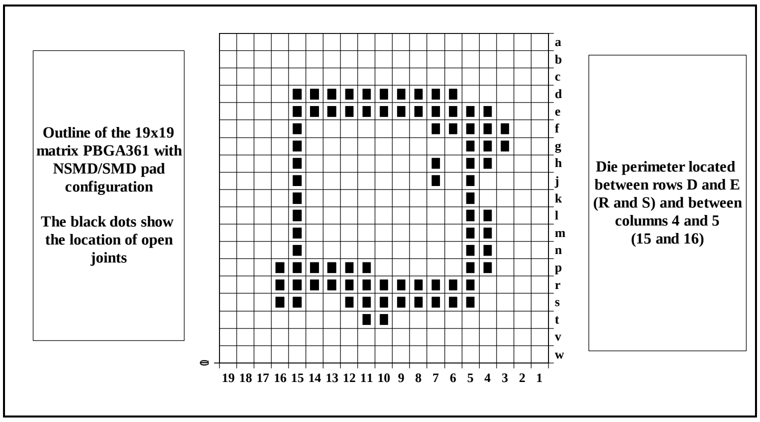

Figure 8. Location of open joints in the Daisy Chain circuit of a PBGA361 with NSMD/SMD pad design after 5000 temperature cycles from -40 to 100 °C (1 hour/cycle) [Rörgren 1998].

The occurrence of intermittent failures under temperature cycling conditions was also measured using another test board, to which different types of BGA packages had been mounted. 16 test boards were hooked up to the event detector described above. No failures were observed for neither the PBGA256 nor the QFP reference samples during the 6000 cycle long test. A few intermittent failures were detected for the SBGAs and the TBGA, as given in Table 3. Six out of the 16 test boards had also been exposed to vibration during the high-temperature phase of 250 thermal cycles (three boards from cycle 1032 to 1282, and three more from 2037 to 2287). This, however, did not seem to have any effect on the devices, i.e. the failures either occurred before vibration exposure (SBGA) or within the control group not subjected to vibration (TBGA).

Table 3. Intermittent failure registration during temperature cycling from -40 to 100 °C.

Device Type	No. of Pins	No. of Devices Tested	No. of Cycles to First Failure	No. of Failed Devices at 6000 cycles
PBGA	256	32	-	0
PQFP	160	16	-	0
PQFP	256	16	-	0
SBGA	256	32	527	5
SBGA	352	15	383	4
TBGA	240	31	3478	15

Recent studies involving ceramic BGAs generally show lower reliability than for plastic packages when mounted to organic substrates like FR-4, even though the CBGAs do not posses coplanarity problems as commonly found with PBGAs (Ghaffarian 1998).

2.2 Production Issues

2.2.1 Design rules and compatibility

As shown in 2.1.4. the reliability of the BGA joint is heavily dependant on the package pad design, and to a lesser extent, the motherboard pad design. The question ”Solder mask defined or non-solder mask defined pad?” is of crucial importance, and the answer needs some thought. Figures 9 and 10 illustrates the differences between these SMD and NSMD pads, as they are most commonly referred to.

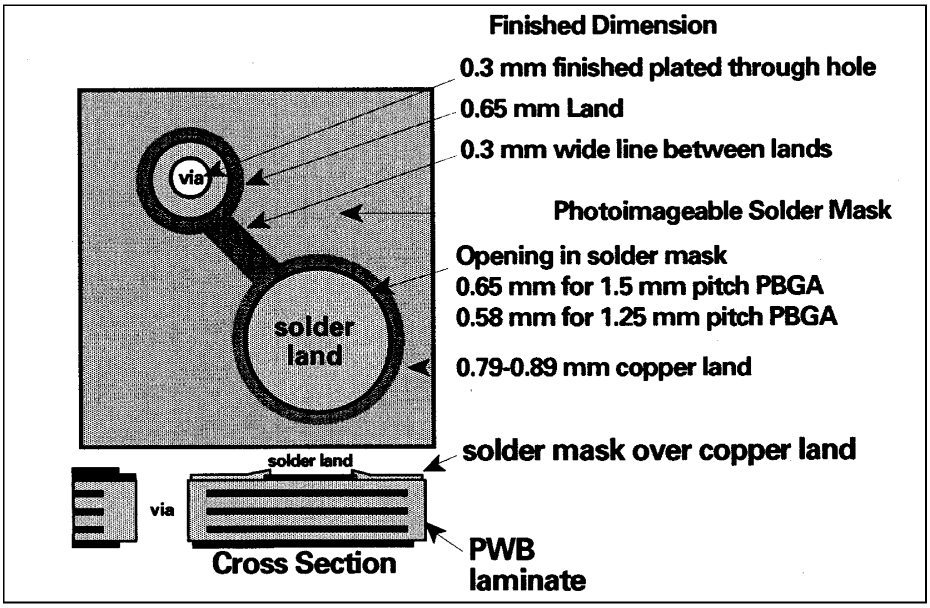

Figure 9. Solder Mask Defined (SMD) pad design for PBGA.

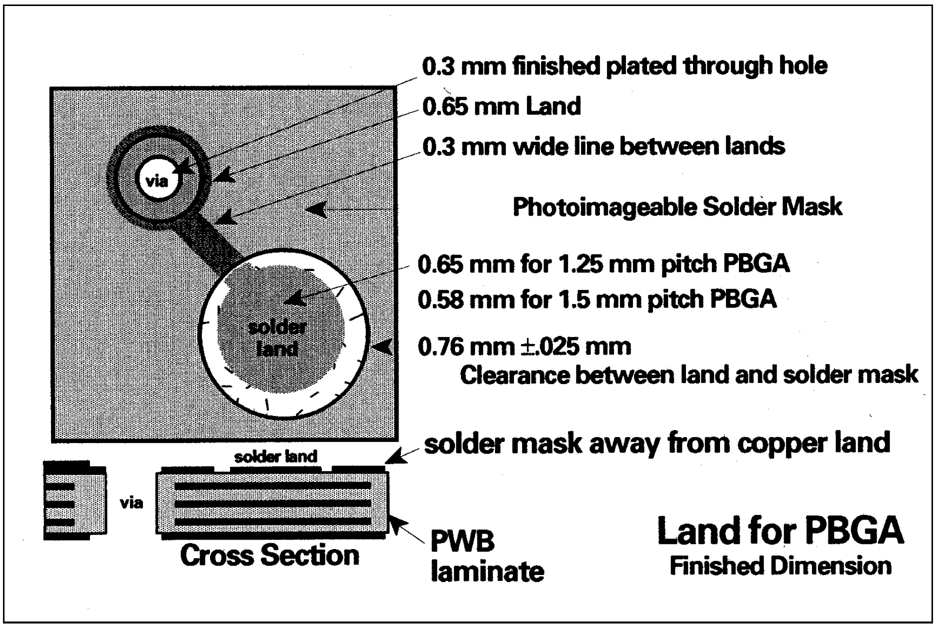

Figure 10. Non-Solder Mask Defined (NSMD) pad design for PBGA.

Clearly, the use of NSMD at BOTH package and motherboard gives optimum reliability and hence longer life owing to a lower stress concentration in the joints (Rörgren 1998). The use of SMD pads results in a higher joint stand-of, which with the same pad configuration would improve performance, but early failures are encountered as cracks are initiating at the edge of the solder mask. However, when NSMD BGA packages are not available, it is not very wise to chose NSMD pads on the motherboard. It is therefore recommended to use the same type of pad designs and of course NSMD if available. Determine the type and diameter of the BGA pads and use the same type on the motherboard, maybe somewhat smaller since stress concentration is higher on the BGA side. Designing with NSMD pads can be more difficult since tolerances get more critical and routing may get tighter. An increased risk of motherboard pad lift (delamination) has also been discussed for NSMD pads.

2.2.2 Tools and investments

In general, no special tooling or equipment is needed in order to use BGA packages in a conventional SMT assembly line,. Hence, no additional investments are generally needed, except for circumstances under which inspection has to be made by means of x-ray (see 2.2.5). Thus, ordinary equipment such as stencil printers, pick & placement machines, and reflow ovens are usually more than adequate from a production point of view. Rework and repair stations intended for fine pitch QFPs are equally well suited for BGA rework tasks.

Equipment for real-time x-ray analysis, in-line or for batch use, are available from a number of equipment manufacturers. Some of the most well known are listed below. The price of even a simpler piece of x-ray equipment can be rather steep. There are possibilities to rent x-ray equipment for process set-up or there are several research facilities or institutes throughout the world providing x-ray analyses on an hourly charge.

- Feinfocus Röntgentechnik GmbH, Germany (http://www.feinfocus.com/)
- HP Four Pi (x-ray Laminography), USA (http://www.tmo.hp.com/tmo/pia/wirelessiia/PIAProd/English/wireless_other_xray.html)
- Nicolet Imaging Systems, USA (http://www.nicimg.com/)

2.2.3 Assembly issues

Assembly using BGA packages is, in principle, rather straight forward. The SMT processes used are essentially the same as for fine-pitch QFPs. Companies already using BGAs have reported significantly improved yield figures as well as increased productivity levels. As an example, switching from 0.5 mm QFP to BGA permitted a major multinational manufacturer to lower the assembly defect ratio from 200-300 ppm down to only 3 ppm. However, there are some areas of concern if care is not taken to observe all the particulars (and they are often changing) about new BGA packaging concepts. To minimize the occurrence of assembly defects, examples of which are given in 2.2.4 , some rules-of-thumb may be worth adhering to.

- Check both PCB and BGA planarity, as warpage often results in open or otherwise defective joints
- Select appropriate solder paste (flux, particle size etc) compatible with solder mask and chemicals used
- Select suitable reflow profile with respect to paste and components. Measure the BGA joint temperature
- Make sure the PBGA packages are moisture-free - or have them baked
- Assure good wetting is achieved, or you may encounter voids and solder balls
- Always use fresh paste. Do not exceed shelf life or open time.
- Remember: Solder paste is hygroscopic. Check ambient conditions regularly.

<u>Solder paste deposition</u>
The most common way to apply solder paste for BGA assembly is by means of screen or stencil printing. The process is in principle the same as for QFPs. Since BGAs typically use a pitch far coarser than for (fine-pitch) QFP, the stencil used can also be thicker. However, when dealing with eutectic solder spheres, it is actually not the BGA that determines the thickness of the stencil but other, mainly, fine-pitch components. This is because roughly 90 percent of the solder volume of the final BGA joint comes from the reflowed solder sphere itself. Some manufacturers even use only a tacky flux for attaching BGAs, and it works very well, but this is not generally recommended since the solder paste deposit helps overcome coplanarity problems which are frequently encountered PBGAs. When using non-eutectic solder spheres, as is the case for TBGAs, the paste deposit and hence stencil thickness becomes a much more important parameter. S <a rule of thumb, select a stencil thickness as a compromise with major emphasis o the finest pitch used on the board.

Just as for ordinary SMT, there are several different types of stencils to chose from. Chemically etched stencils are the most economic and established alternative, while additively processed stencils, often referred to as electroformed, are the state of the art for very fine pitch applications - and thus rather costly.

Following the argument above, the BGA technology itself does not require the use of any exotic (costly) stencil type owing to the rather large pitch and with it the possibility to use relatively coarse-grain solder pastes. Also bear in mind that a laser cut stencil, being a very wise choice for ultra fine pitch QFPs, becomes quite expensive for large I/O BGA purposes since laser cutting is a sequential process and each hole in the mask adds to the total cost. Thus, chose a conventional, 200 µm thick, chemically etched stencil, unless you in addition to BGAs also are putting very fine pitch packages on the assembly. If so, let the very fine pitch determine the choice.

Device placement

The PBGA exhibits a strong self centering effect, so precise alignment is not critical. Up to 0.3 mm of misalignment has been reported not to cause any excessive bridging after reflow. In most cases, conventional placement systems can be employed, using either the package outline or the position of the solder spheres as a placement guide. Vision systems may also be used, increasing the productivity, though a few problems have been encountered. Firstly, it has been reported that the colour of the back side, i.e. the substrate laminate) of PBGs may vary from manufacturer to manufacturer or even worse, from batch to batch. This means that when automatic vision alignment is employed, the threshold or acceptance level must be adjustable, and adjusted if varying colours are encountered. Furthermore, some early vision systems were not capable of using all the solder spheres for optical alignment, nor were they able to check whether all spheres were present. These older systems, typically using only the outer row of solder spheres, are now becoming obsolete and are getting replaced and in the near future this problem should not be heard of any more. A modern vision system should also be able to optically align a BGA package with corner balls removed and/or with additional thermal balls without any interference to the alignment procedure.

Reflow soldering

The method of choice for soldering BGAs is of course mass reflow soldering. This can be performed in several different ways using nitrogen, air, IR, full or partly convection, in almost the same ways as when soldering QFP assemblies. One difference is the thermal mass of a BGA package, in general being somewhat higher. This means that there is a slight risk of having too low a temperature i the middle of a BGA while small chip components still get a little too hot. This is particularly true if IR and/or ceramic packages are used. With a properly run convection oven, a temperature difference of 5 - 8 degrees measured as described above should be attainable. To achieve this, a slightly slower belt speed may help, together with a little lower reflow peak temperature. However, measurements of the actual joint temperature are always necessary in order to optimize the process.

One other major issue of concern when using plastic BGA packages, is the fact that they indeed are sensitive to humidity. PBGAs are not hermetically sealed and, due to package construction with non-covered substrate edges, they will absorb moisture while in storage. If the package is heated too quickly, such as during reflow, the package will crack (the ”pocorn” effect) from steam pressure build-up. It is therefore of utmost importance to assure that the plastic packages have been kept in their dry packs and have not been exposed to ambient conditions for more than the specified or accepted period of time. If you are not sure of the packages history; make sure you have them baked again, e.g. at 125 °C for 24 hours.

2.2.4 Inspection and Workmanship Standards

Assembly defects related to defective solder joints are generally thought to be detected in the final production stage, being either visual inspection or functional testing, or both. Failures not detected or any defects that will eventually lead to a failure with time or environmental exposure, are in this context treated as a reliability concern, as discussed in 2.1.4.

The most likely defects to observe upon inspection include all or most of the following:

- Placement accuracy
- Solder bridging (short-circuits)
- No contact (opens)
- Excessive or insufficient solder
- Solder balling (beads)

- Voids

Because of the ”secret” nature of the BGA package, with the joints hidden under the device, x-ray inspection is really the only possibility to actually inspect all the joints. However, once the process has been set up and qualified using x-ray, a sound statistical process control should be sufficient to maintain the quality goal. Most of the defects usually encountered, except the hard failures ”shorts” and ”opens” need to be judged according to some sort of Workmanship Standard in order to qualify the solder joint as accepted or not. In addition, flux residues or other types of chemical contamination, as well as signs of cracking (pop-corning) must be taken into consideration. Of course, all of this. Including the acceptance criteria, is depending on the expected service environment of the product and may therefore differ from case to case.

2.2.5 Rework and Repair

Conventional rework stations are often capable of BGA rework as well. There are also equipment especially designed for BGA, incorporating both hot gas and IR heating, to take faulty BGA components off the board of putting new packages down. Redressing of the board site is most often necessary, before new paste (or flux) is applied by mini-stencilling or dispensing. A package removed for some other reason than being defect itself cannot be put back since the eutectic solder spheres will have melted while the package was removed. An obstacle to rework is the case with double sided assembly, generally making rework impossible if the board is densely populated and designed without repair in mind.

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3. Background Information

3.1 Reports

IVF Rapport 95017 ”Övergripande elektriska och termiska krav,” A. Sihlbom, H. Svärd (in Swedish)

IVF Rapport 95037 "Sammanställning av möjliga felmekanismer på kretskortsnivårelaterade till tillverkning och driftsmiljö för primärt BGA- och QFP-komponenter", P.-E. Tegehall (in Swedish)

IVF Rapport 95038 "Redovisning av förväntade felmekanismer på kretskortsnivå för BGA- och QFP-komponener i fordonselektronik", P.-E. Tegehall (in Swedish)

IVF Rapport 95039 "Sammanställning av miljöprovningsmetoder för utvärderingen av tillförlitligheten av BGA- och QFP-komponenter", P. Carlsson, P.-E. Tegehall (in Swedish)

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3.2 Papers

Paper "A comparative study of ball grid array and ultra fine-pitch QFP technologies using solder paste stencil printing," Rörgren, P. Carlsson, J. Liu, Proceedings Surface Mount International, San Jose, CA, Aug 29-31, 1995.

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[2] J. S. Hwang, ”Ball Grid Array & Fine Pitch Peripheral Interconnections”, ISBN 0 901150 29 0, Electrochemical Publications Ltd, Isle of Man 1995

[3] T. L. Landers et al, ”Electronics Manufacturing Processes”, ISBN 0-13-176470-5, Prentice Hall. Englewood Cliffs 1994

[4] J. H. Lau (ed.), ”Ball grid array technology,” ISBN 0-07-036608-X, McGraw-Hill, New York 1995

[5] Joint Industry Standard ANSI/J-STD-013, ”Implementation of Ball Grid Array and Other High Density Technology”, IPC - The institute for Interconnecting and Packaging Electronics Circuits, 2215 Sanders Road, Northbrook, IL 60062-6135, USA

4.2 National reports

VI Forskningsrapport V040037A "Utvärdering av byggsättsteknik för produktion med BGA- och fine-pitch QFP-kapslar," R. Rörgren, P. Carlsson, J. Liu, 1995 (in Swedish)

Rapport BEE/A/BE/001 "Produktionskrav BGA på mönsterkort", Lars Wåhlström, Berifors (in Swedish)

Rapport BEE/C/BE/002 "Process för montering av BGA till mönsterkort/Konstruktionsmetodik för kretskort med BGA", Lars Wåhlström, Berifors (in Swedish)

4.3 Papers

Paper "BGA-MCM technology for harsh environmental applications", P. Haglund, P. Frisk, J.-O. Andersson, ISHM-Europe, 14-16 May 1997, Venice, Italy

Paper ”BGAs for high reliability applications,” R. Ghaffarian, Electronics Packaging & Production, Vol. 38, No. 3, pp.45-52, March 1998.

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4.4 Conferences

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IMAPS: http://www.imaps.org

Surface Mount International: http://www.smta-international.com