SOLDER RELIABILITY SOLUTIONS APPLICATION NOTE
- CAVITY DOWN BALL GRID ARRAYS ON FR-4

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SUMMARY

This technical note illustrates the application of the SRS model to cavity down BGAs on printed wiring boards. Models are developed for 352 and 560 I/O SuperBGAs (SBGAs) and 540 I/O Enhanced BGAs (EBGAs) on FR-4. Assumptions of package-specific models are discussed and input parameters are given for six different types of cavity-down BGA assemblies. Solder joint life predictions for cavity-down BGA assemblies are in good agreement with accelerated thermal cycling test results.

CAVITY DOWN BGAs

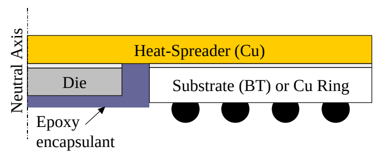
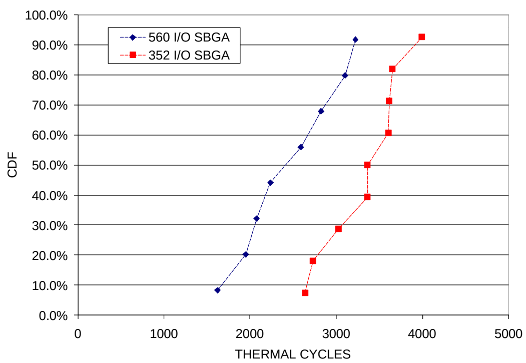


Figure 1: Schematic cross-section of cavity-down BGA.

A cavity down BGA is a perimeter BGA with solder balls attached to a BT substrate or copper ring. A schematic cross-section of a cavity down BGA is shown in Figure 1. Only half of the component section is shown with the component neutral axis on the left. The back of the die is attached to a heat-spreader with conventional die attach epoxy. First level interconnections are provided by wire bonding to the layered BT substrate or to the copper ring with thin polyimide layers at the bottom.

SUPERBGA TEST DATA



Failure Number	Cycles to Failure SBGA352	SBGA560
1	2636	1621
2	2729	1947
3	3027	2077
4	3363	2236
5	3363	2590
6	3605	2823
7	3614	3102
8	3652	3224
9	3996	na

	α (cycles)	β (2P Weibull)
SBGA560	2676	4.58
SBGA352	3522	8.07

Figure 2: SBGA solder joint failure cycles and distributions (CDF = Cumulative Distribution of Failures).

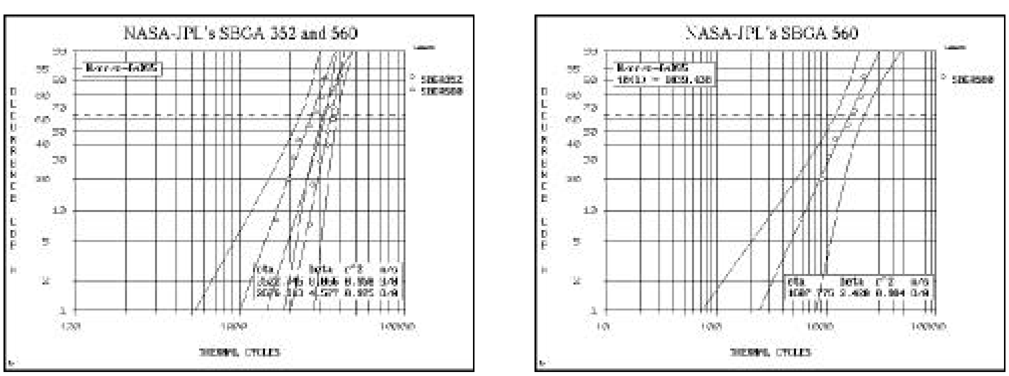
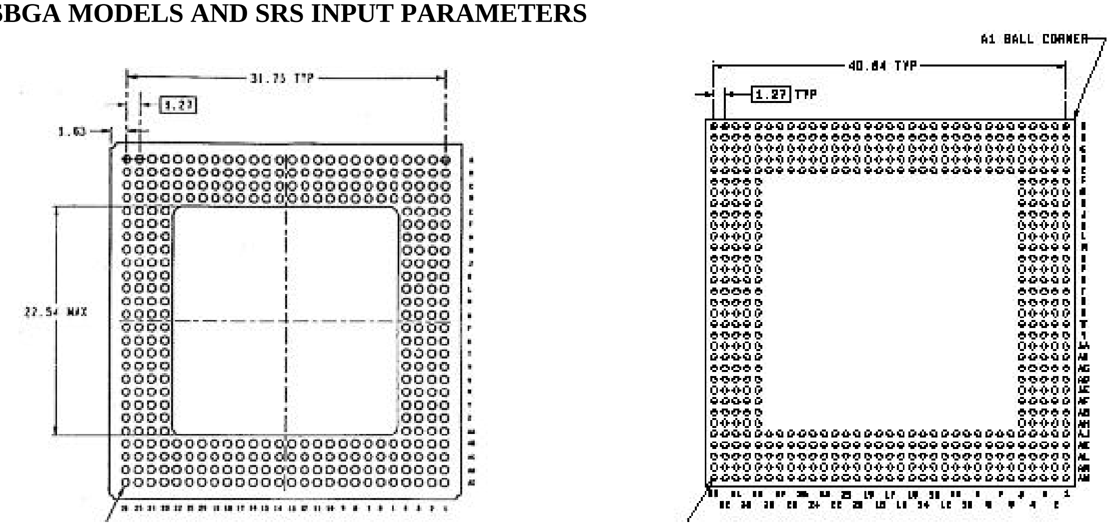


Figure 3: 2P Weibull plot (left) and 3P Weibull plot (right) of SBGA failure data.

The 1.27 mm pitch SBGAs tested by the JPL consortium were 352 I/O (35 mm square) and 560 I/O (42 mm square) SuperBGAs on 59 mil thick FR-4. Accelerated thermal conditions were from -55 to 125ºC with 10 to 15ºC/min. ramps, 20-minute dwells and a cycle duration of 68 minutes (21.176 cycles/day). Detailed information on the JPL's test vehicles, test procedures, failure analysis and failure data can be found in publications by R. Ghaffarian (1997-99) as well as in the project report distributed by ITRI (1998).

Failure distributions are plotted in Figures 1 and 2. Figure 1 gives the cycles to failure as measured on plots of failure distributions in the ITRI report. Also tabulated is a summary of 2P Weibull parameters: the characteristic lives, α, and the slope or shape parameters, β, of the 2P Weibull distributions. Figure 2 (left) shows 2P Weibull distributions for the 352 and 560 I/O SBGA assemblies. Figure 2 (right) shows the 3P Weibull distributions for the 560 I/O SBGA assemblies. A 3P Weibull plot is not available for the 352 I/O SBGAs since the 3P Weibull analysis for that dataset gave a negative failure free time. This is possibly because the sample size was small.

SBGA MODELS AND SRS INPUT PARAMETERS



Maximum DNP = 22.45 mm = 0.8838 inch

Maximum DNP = 28.74 mm = 1.131 inch

Figure 3: Package pad layout for 352 I/O SBGA (left) and 560 I/O SBGA (right) - units: mm (drawings after National Semiconductor web site).

The SBGAs of the NASA-JPL test vehicles have a copper heat-spreader *and* a copper ring with a measured CTE of 16.3 ppm/ºC. We make the simplifying assumption that the SBGA package can be modeled as an "all copper" component, that is, a single copper plate of thickness the package thickness (23.2 mil) and with a CTE equal to the CTE of copper. We thus neglect any possible encapsulant and die effect, contrary to the strong die size effect observed in full-array, overmolded PBGAs. This is a reasonable simplification since the encapsulant is a rather soft material and the die is attached to a somewhat stiff heat-spreader. The die attach also provides for decoupling between the die and the heat-spreader. In addition, because the die is smaller than the package cavity, the solder balls on the package perimeter probably do not feel much of the low expansion of silicon. Last, to our knowledge, the die size has not been reported as an influential factor in test results on cavity down BGA assemblies.

The SBGA package is modeled using the "LCCC" component type in the SRS pre-processor component options with the component being "all copper". The analysis files are set up for the outermost corner joints with maximum DNPs as shown in Figure 3. The reasoning for this is that moiré analysis of solder joint strains and thermal cycling of cavity down BGAs indicate that the outermost corner joints tend to fail first (Ejim et al., 1997). The "LCCC" component windows and pre-processor data for both the 352 and 560 I/O SBGAs are given in Appendix A.

Critical parameters that required accurate input of nominal values were obtained from the ITRI report and from Dr. Reza Ghaffarian of NASA-JPL:

- Package thickness: 23.2 mil (measured)
- Component CTE ("copper" specialty alloy): 16.3 ppm/ºC (measured)
- FR-4 in-plane CTE: 14.4 ppm/ºC (measured)
- FR-4 board thickness: 58.6 mil (measured)
- Corner joint height: h_S = 19.2 mil (measured at corner joint)
- Copper properties: Young's modulus: $E = 17 \times 10^6$ psi; Poisson's ratio: $\nu = 0.38$
- From joint cross-sections in the ITRI report, we estimated that the SBGA wetted pad area had a nominal diameter of 22 mil. This gives a solder joint crack area: $A = 3.8 \times 10^{-4}$ in^2.

A few other observations are noteworthy:

- For the number of "susceptible" or critical I/Os, we use k = 4 corners x 3 joints = 12 joints to account for each corner joint and the pair of adjacent joints on the outer row of solder joints. This is somewhat arbitrary and does not matter much since a different choice of k, say k = 4 or 16, would result in a different model calibration factor in the final analysis (see results discussion). What matters is to keep the selected number of I/Os, N, consistent from one analysis to the next.

- Note the importance of using measured CTEs for both the board and the package. In the NASA JPL test vehicles, the FR-4 board has an in-plane CTE of 14.4 ppm/ºC while numbers like 16 to 18 ppm/ºC are often quoted as "typical" nominal values.

- For the SBGA packages, Amkor’s data sheet (available on the web) gives an effective CTE in the narrow range 15 to 16.3 ppm/ºC. With our simplifying assumption that the package is "all copper", the component CTE is 16.3 ppm/ºC, which matches the upper bound of Amkor's CTE range.

- Using accurate CTE values is important because, in the case of the SBGA test vehicles, the package-to-board CTE mismatch is small: $\Delta\alpha = 16.3 - 14.4 = 1.9$ ppm/ºC. Even though the package is apparently well CTE-matched to the boards, cyclic shear strains $\Delta\gamma$ in the corner joints are large because of the large DNPs and the large temperature swings ΔT:
  - For the 352 I/O SBGAs: $$\Delta\gamma = \frac{DNP_{max}\Delta\alpha\Delta T}{h_S} = \frac{0.8838 \times 1.9 \cdot 10^{-6} \times 180}{19.2 \cdot 10^{-3}} = 1.57\%$$
  - For the 560 I/O SBGAs: $$\Delta\gamma = \frac{DNP_{max}\Delta\alpha\Delta T}{h_S} = \frac{1.131 \times 1.9 \cdot 10^{-6} \times 180}{19.2 \cdot 10^{-3}} = 2.01\%$$

Past experience with leadless components such as LCCCs suggest that cyclic shear strains of the order of 1% raise a red flag since they lead to failures in a few hundred cycles, or 1000-2000 cycles when the solder crack area is sufficiently large, which is the case with SBGAs. The size of SBGA packages may be a reliability-limiting factor.

EBGA TEST DATA

Reflow	BT Thickness	α_{comp} (cycles)	2P Weibull β
Single	0.75 mm	8328	6.9
Double	0.75 mm	9271	5.1
Single	1 mm	8157	4.9
Double	1 mm	8695	4.6

Table 1: 540 I/O EBGA test matrix and 2P Weibull results (after Ejim et al., 1997)

Next, we analyze four variations of 540 I/O Enhanced BGAs (EBGAs) assemblies that were tested by Ejim et al. (1997) of Lucent Technologies. Test conditions were thermal cycling between 0ºC and 100C with dwell times of about 5 minutes and a test frequency of 72 cycles per day. These EBGAs have a copper heat-spreader and a BT substrate that is 0.75 mm (29.53 mil) or 1 mm (39.37 mil) thick. For single reflow assemblies, the standoff height was 0.46 mm (18.11 mil). For double reflow assemblies, the joints were stretched to a height of 0.68 mm (26.77 mil). The test matrix and test results from Ejim et al. (1997) are summarized in Table 1. For further information on the EBGA tests, the reader is referred to the original publication by Ejim et al. (1997).

EBGA MODELS AND SRS INPUT PARAMETERS

The input data for the 4 types of EBGA assemblies are in Appendix B. As a first order simplification, the EBGAs are treated as packages with two layers, one for the BT substrate, one for the copper heat-spreader. The EBGAs are modeled using the "full array PBGA" component option with input as shown in the figures of Appendix B. Thus, for simplification purposes, we neglect any possible effect of the die and the encapsulant. This simplification is justified a-posteriori by comparing test results and life predictions.

The two-layer model for EBGA packages accounts for thermal expansion, stretching and flexing of the two layers. In the input windows shown in Appendix B, we use the substrate core layer for the BT substrate and the next layer up for the copper heat-spreader. The other cells of the multi-layer model are zeroed out although they could possibly be used to account for the adhesive layer between the heat-spreader and the BT substrate. Cells of the "solder mask" layer at the bottom of the multi-layer model are also zeroed out so the model gives the proper package thickness at the copper pad location.

Assumptions made in the input data are as follows:

- Ejim et al. (1997) give an average board-to-component CTE mismatch: $\Delta\alpha$ = 1.0 ppm/ºC. Thus, for each EBGA model, we use the component CTE computed by the software and add 1.0 ppm/ºC to it to set the value of the board in-plane CTE in the pre-processor.

- The small CTE mismatch, $\Delta\alpha$, is an average value since package and board CTEs have their own variability and the accuracy of CTE measurement techniques is of the order of 0.5 to 1 ppm/ºC.

- The heat-spreader thickness was estimated from assembly cross-sections in Figure 7 in Ejim et al.'s paper.

- The standoff heights are h_S = 0.46 mm (18.1 mil) for the "single reflow" assemblies and h_S = 0.68 mm (26.7 mil) for the "double reflow" assemblies. These values were given for EBGAs with 1 mm BT. Standoff heights were not given for the EBGAs with 0.75 mm BT, so we assume they are approximately the same as for EBGAs with 1 mm BT.

- The pad layout was not available either for the 1.27 mm pitch, 540 I/O EBGAs. However, this package is similar in size to JPL's 560 I/O SBGA, so we use the same maximum DNP as in the SBGA models discussed earlier.

A simplified shear strain model gives maximum cyclic shear strains as follows:

- For "single reflow" assemblies: $$\Delta\gamma = \frac{DNP_{max}\Delta\alpha\Delta T}{h_S} = \frac{1.131 \times 1.0 \cdot 10^{-6} \times 100}{18.1 \cdot 10^{-3}} = 0.62\%$$

- For "double-reflow" assemblies: $$\Delta\gamma = \frac{DNP_{max}\Delta\alpha\Delta T}{h_S} = \frac{1.131 \times 1.0 \cdot 10^{-6} \times 100}{26.7 \cdot 10^{-3}} = 0.42\%$$

The shear strains are of the order of 0.5%, that is, they are still high and solder joint failures are expected in a reasonable amount of time under accelerated thermal cycling conditions. However, failures occur later than with LCCCs because of the large solder joint load bearing and crack propagation areas in EBGA assemblies. Weibull distributions in Figure 4 of Ejim et al.'s paper (1997) show first failures in the range 3500 to 5000 cycles.

SRS POST-PROCESSING AND COMPARISON TO TEST DATA

Component	α_{comp} (cycles)	2P Weibull β	ΔW_{in} (psi)	α_{joint} / A (cycles/in^2)
560 I/O SBGA	2676	4.577	4.624	1.18E+07
352 I/O SBGA	3522	8.066	4.298	1.23E+07
540 I/O EBGA: 1 mm BT, Single Reflow	8157	4.9	1.415	3.56E+07
540 I/O EBGA: 1 mm BT, Double Reflow	8695	4.6	1.146	3.93E+07
540 I/O EBGA: 0.75 mm BT, Single Reflow	8328	6.9	1.533	3.14E+07
540 I/O EBGA: 0.75 mm BT, Double Reflow	9271	5.1	1.215	3.97E+07

Table 2: Test results (α_{comp}, β) and data points plotted in Figure 3.

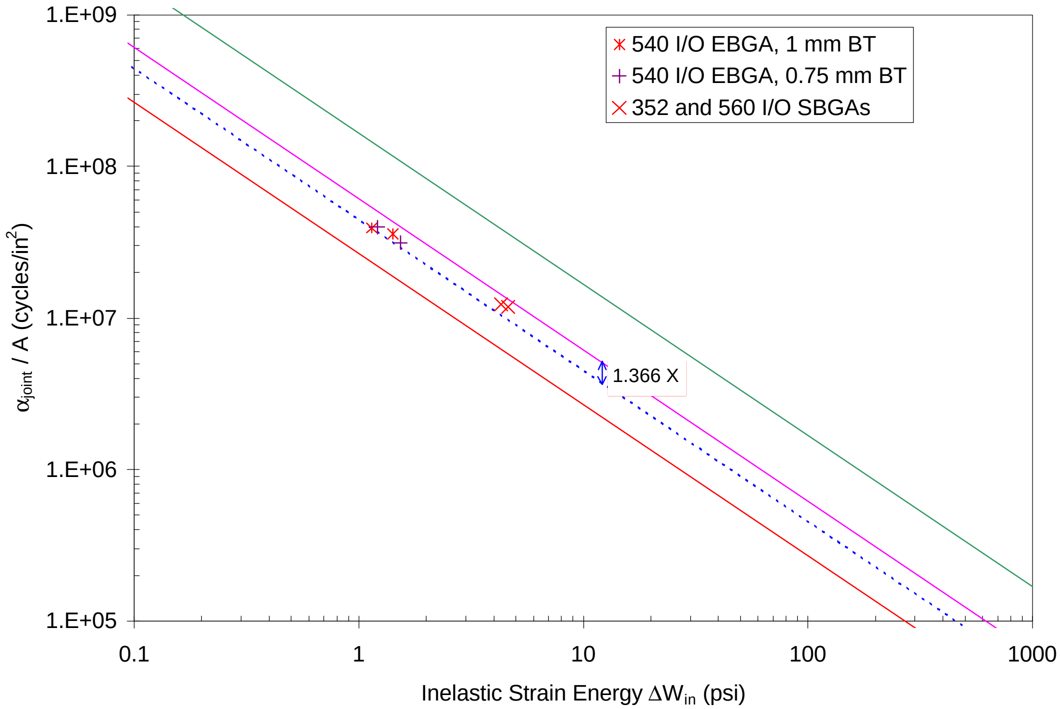


Figure 4: Fit of SBGA / EBGA test results to SRS model correlation.

The post-processor of the SRS software gives the cyclic inelastic strain energy, ΔW_{in}, for each test vehicle and test condition (see Table 2). The data is plotted on the SRS correlation plot in Figure 4 where the equation of the model centerline is (Clech, 1996): $\frac{\alpha_{JOINT}}{A} = \frac{6.149 \times 10^7 \times C}{\Delta W^{0.998}}$ where C is the model calibration factor. C equals 1 for the centerline of the correlation band, 0.434 for the lower bound, and 2.7 for the upper bound of the correlation band.

For each data point shown in Figure 4, the characteristic life, α_{joint}, scaled for the crack area (A = 3.8 x 10^{-4} in^2 for the cavity-down BGAs described earlier) is on a joint per joint basis. The joint characteristic life, α_{joint}, is obtained from the component characteristic life, α_{comp}, using the statistical transformation: $\alpha_{JOINT} = \alpha_{COMP} \times k^{1/\beta}$ where k is the number of critical or "susceptible" I/Os, that is, k is the number of component joints most susceptible to fail. As discussed earlier, we used k = 12 for the cavity-down BGAs. A different choice of k would result in a slight offset of the data points in Figure 4.

As can be seen in Figure 4, the cavity-down BGA data falls nicely within the SRS correlation band:

- The data is off the centerline by a factor of at most 1.366 times. That is, for similar test vehicles and packages, a suggested model calibration factor is: C = 1/1.366 = 0.73 which should probably be rounded off to C 0.7.

- A trendline (not shown in Figure 4) that is fit through the 6 cavity-down BGA data points has a slope of -0.9, close to the slope (-1) of the model centerline. This suggests consistency between the SBGA and EBGA test results as well as linear acceleration between the NASA-JPL and Lucent test conditions. Variability in design parameters and uncertainty in some of the EBGA input parameters are one possible source of the slight discrepancy in the two slopes.

Component	α_{comp} (cycles)		Ratio	$N_{50\%}$ (cycles)
	Test	SRS Prediction	Test / SRS Pred.	IPC-SM785
560 I/O SBGA	2676	2946	1.101	2398
352 I/O SBGA	3522	4007	1.138	4198
540 I/O EBGA: 1 mm BT, Single Reflow	8157	9953	1.220	62088
540 I/O EBGA: 1 mm BT, Double Reflow	8695	11880	1.366	165162
540 I/O EBGA: 0.75 mm BT, Single Reflow	8328	10640	1.278	62088
540 I/O EBGA: 0.75 mm BT, Double Reflow	9271	11820	1.275	165162

Table 3: Comparison of measured and predicted fatigue lives on a component basis.

Table 3 shows a comparison of measured and predicted characteristic lives on a component basis. The SRS life predictions are given in the SRS post-processor assuming a model calibration factor C = 1, i.e., the life predictions are based on the model centerline.

- For the SuperBGAs, for which we had accurate input parameters, the discrepancy between test results and the SRS predictions is 10 to 14%.

- For the EBGAs, some of the SRS input parameters were not known accurately and the discrepancy is slightly larger, in the range 22% to 37%. Simplifications in the package modeling technique contribute to the discrepancy as well.

- Nevertheless, the agreement between test results and SRS life predictions is thought to be acceptable since the accuracy of fatigue life models is at best within a factor of two times.

Table 3 also gives cycles to 50% failures - i.e. $N_{50\%}$, which is close to the characteristic life of Weibull distributions - as obtained from the IPC-SM785 life prediction model:

- For the SBGAs under conditions -55ºC to 125°C, the agreement with the test data is very good.

- For the EBGAs under conditions 0ºC to 100°C, the IPC model over-predicts fatigue lives. The discrepancy with the test data is a factor 8 to 19 times.

- The two findings above are perplexing since IPC-SM785 states that the IPC model does not apply to temperature ranges that have a cold temperature below -20ºC. On the other hand, the model is supposed to apply in the range 0ºC to 100°C but this does not seem to apply to the EBGA test and EBGA assemblies.

ACKNOWLEDGMENTS
The author thanks Dr. Theo Ejim of Lucent Technologies for discussions on his and his co-authors' paper on EBGA assemblies. The author is also grateful to Dr. Reza Ghaffarian of NASA's Jet Propulsion Laboratory for discussions on the BGA consortium report and for providing some of the critical input parameters that the author did not guess accurately in his initial analysis of SBGA solder joint failures.

REFERENCES

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APPENDIX A: SBGA - SRS INPUT DATA FOR 352 AND 560 I/O SBGAs

352 I/O SBGA

INPUT OF SOLDER RELIABILITY SOLUTIONS PROGRAM SRS file name: SBGA352.SRS Date: 03/29/2000 4:57:37 PM	SUBSTRATE DATA Substrate material: FR-4 Effective in-plane CTE in diagonal direction of component: 1.440E-05 /deg.C Young's modulus in tension: 2.000E06 psi Thickness: 5.860E-02 inch
PROJECT Title: SBGA352 - JPL test Notes: Analysis is done at outermost corner joint	ASSEMBLY DATA Assembly stiffness: 1.387E03 lb/in Solder joint effective thickness: 1.920E-02 inch Solder joint crack area: 3.800E-04 sq.inch

COMPONENT DATA
Name: 352 I/O SBGA
Number of susceptible IOs: 12

Global Mismatch Parameters:
Distance to Neutral Point, DNP: 8.838E-01 inch
Effective CTE: 1.630E-05 /deg.C

Local Mismatch Parameters:
Thickness of lead or component at solder joint: 2.320E-02 inch
Effective CTE of lead or component at solder joint: 1.630E-05 /deg.C
Effective Young's modulus of lead or component at solder joint: 1.700E07 psi

THERMAL CONDITIONS

Number	Temperature C		Dwell min.		Cycles	Name
	Hot	Cold	Hot	Cold		
1	125.0	-55.0	20.0	20.0	21.176 CPD	Condition B (Boeing test)

Note: F = Fixed cycles; CPD = Cycles Per Day for variable type cycles

DESIGN LIFE and STATISTICAL PARAMETERS
Product design life: 5.000 Years
2P Weibull shape parameter (beta): 8.066
3P Weibull ratio: failure free time / characteristic life: 0.500

Table A.1: SRS Model Input Data for 352 I/O SBGA on FR-4.

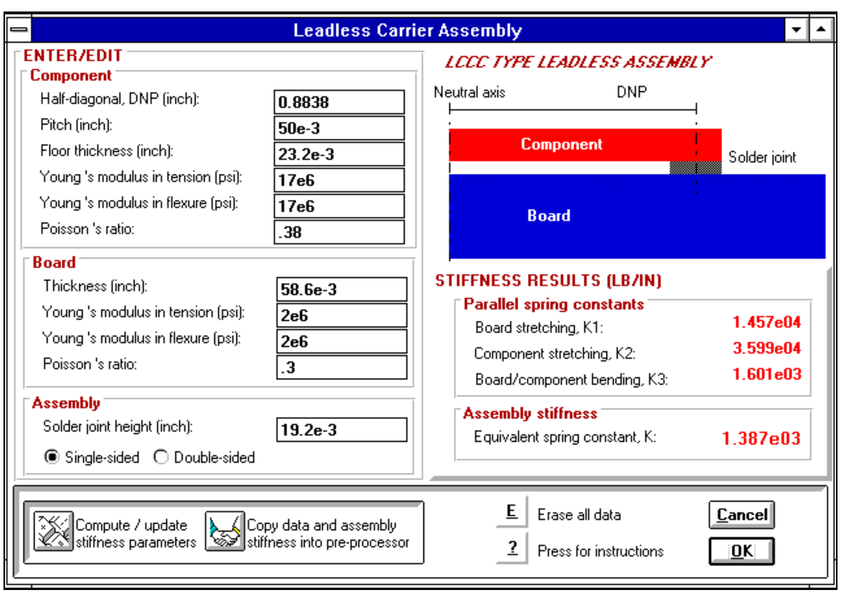

Figure A.1: SBGA352: "LCCC" component window for calculation of assembly stiffness parameter.

560 I/O SBGA

INPUT OF SOLDER RELIABILITY SOLUTIONS PROGRAM SRS file name: SBGA560.SRS Date: 03/29/2000 5:01:54 PM	SUBSTRATE DATA Substrate material: FR-4 Effective in-plane CTE in diagonal direction of component: 1.440E-05 /deg.C Young's modulus in tension: 2.000E06 psi Thickness: 5.860E-02 inch
PROJECT Title: SBGA560 - JPL test Notes: Analysis is done at outermost corner joint	ASSEMBLY DATA Assembly stiffness: 1.084E03 lb/in Solder joint effective thickness: 1.920E-02 inch Solder joint crack area: 3.800E-04 sq.inch

COMPONENT DATA
Name: 560 I/O SBGA
Number of susceptible IOs: 12

Global Mismatch Parameters:
Distance to Neutral Point, DNP: 1.131E00 inch
Effective CTE: 1.6300E-05 /deg.C

Local Mismatch Parameters:
Thickness of lead or component at solder joint: 2.320E-02 inch
Effective CTE of lead or component at solder joint: 1.630E-05 /deg.C
Effective Young's modulus of lead or component at solder joint: 1.700E07 psi

THERMAL CONDITIONS

Number	Temperature C		Dwell min.		Cycles	Name
	Hot	Cold	Hot	Cold		
1	125.0	-55.0	20.0	20.0	21.176 CPD	Condition B (Boeing test)

Note: F = Fixed cycles; CPD = Cycles Per Day for variable type cycles

DESIGN LIFE and STATISTICAL PARAMETERS
Product design life: 5.000 Years
2P Weibull shape parameter (beta): 4.577
3P Weibull ratio: failure free time / characteristic life: 0.393

Table A.2: SRS Model Input Data for 560 I/O SBGA on FR-4.

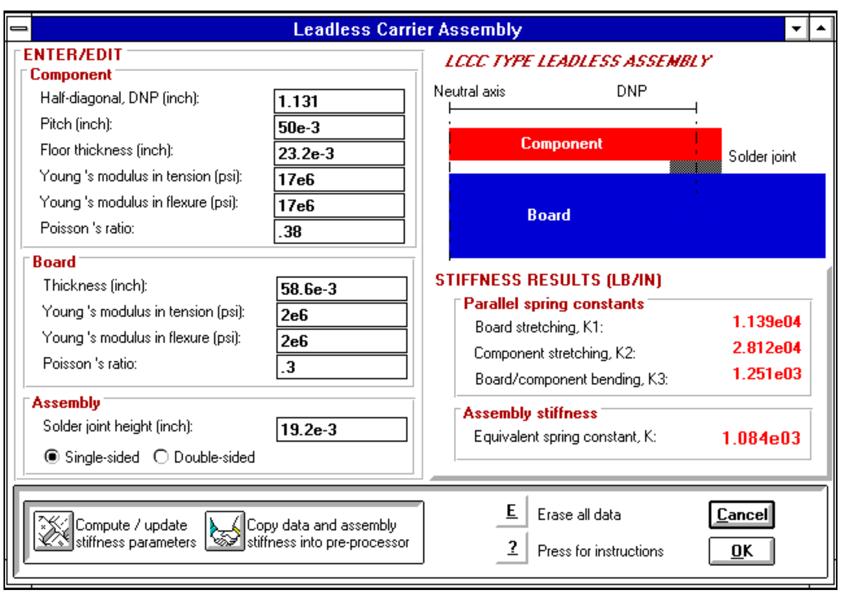

Figure A.2: SBGA560: "LCCC" component window for calculation of assembly stiffness parameter.

APPENDIX B: SRS INPUT DATA FOR 540 I/O EBGAs

540 I/O EBGA, 0.75 mm BT, "single reflow"

INPUT OF SOLDER RELIABILITY SOLUTIONS PROGRAM

SRS file name: EBG540AS.SRS
Date: 04/03/2000 11:14:43 AM

SUBSTRATE DATA
Substrate material: FR-4
Effective in-plane CTE in diagonal direction of component: 1.695E-05 /deg.C
Young's modulus in tension: 2.000E06 psi
Thickness: 6.200E-02 inch

PROJECT
Title: SBGA540, 0.75 mm BT, vendor A; 'single side reflow'- Lucent's test
Notes:
Analysis is at outermost corner joint. BT is 0.75 mm thick.

ASSEMBLY DATA
Assembly stiffness: 3.230E03 lb/in
Solder joint effective thickness: 1.810E-02 inch
Solder joint crack area: 3.800E-04 sq.inch

COMPONENT DATA
Name: 560 I/O SBGA
Number of susceptible IOs: 12

Global Mismatch Parameters:
Distance to Neutral Point, DNP: 1.113E00 inch
Effective CTE: 1.595E-05 /deg.C

Local Mismatch Parameters:
Thickness of lead or component at solder joint: 1.053E-01 inch
Effective CTE of lead or component at solder joint: 1.626E-05 /deg.C
Effective Young's modulus of lead or component at solder joint: 1.279E07 psi

THERMAL CONDITIONS

Number	Temperature C		Dwell min.		Cycles	Name
	Hot	Cold	Hot	Cold		
1	100.0	0.0	5.0	5.0	72.000 CPD	ATC

Note: F = Fixed cycles; CPD = Cycles Per Day for variable type cycles

DESIGN LIFE and STATISTICAL PARAMETERS
Product design life: 5.000 Years
2P Weibull shape parameter (beta): 6.900
3P Weibull ratio: failure free time / characteristic life: 0.500

Table B.1: SRS Model Input Data for 540 I/O EBGA (0.75 mm BT, single reflow) on FR-4.

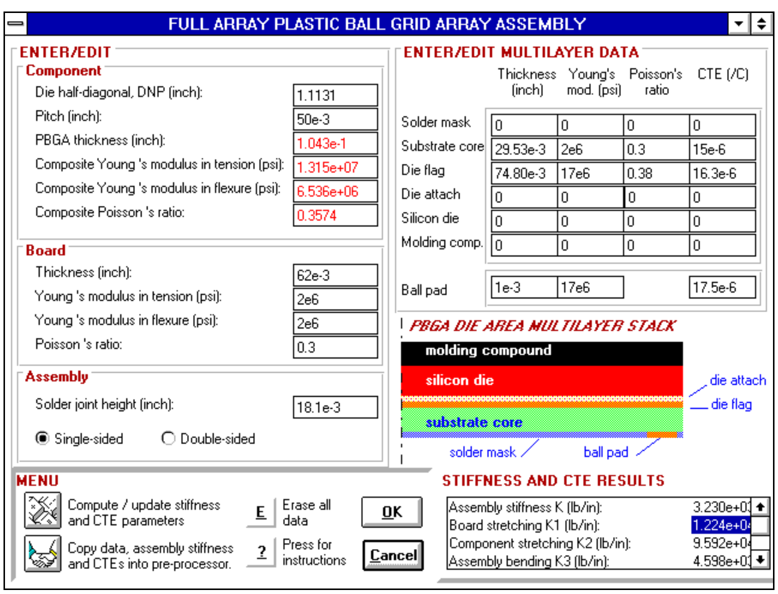

Figure B.1: EBGA540 (0.75 mm BT, single reflow): "PBGA" component window for calculation of assembly stiffness parameter and component effective CTE.

540 I/O EBGA, 0.75 mm BT, "double reflow"

INPUT OF SOLDER RELIABILITY SOLUTIONS PROGRAM

SRS file name: EBG540AD.SRS
Date: 04/03/2000 11:19:07 AM

SUBSTRATE DATA
Substrate material: FR-4
Effective in-plane CTE in diagonal direction of component: 1.695E-05 /deg.C
Young's modulus in tension: 2.000E06 psi
Thickness: 6.200E-02 inch

PROJECT
Title: SBGA540, 0.75 mm BT, 'double side reflow'- Lucent's test
Notes:
Analysis is at outermost corner joint. BT is 0.75 mm thick.

ASSEMBLY DATA
Assembly stiffness: 2.873E03 lb/in
Solder joint effective thickness: 2.670E-02 inch
Solder joint crack area: 3.800E-04 sq.inch

COMPONENT DATA
Name: 560 I/O SBGA
Number of susceptible IOs: 12

Global Mismatch Parameters:
Distance to Neutral Point, DNP: 1.113E00 inch
Effective CTE: 1.595E-05 /deg.C

Local Mismatch Parameters:
Thickness of lead or component at solder joint: 1.053E-01 inch
Effective CTE of lead or component at solder joint: 1.626E-05 /deg.C
Effective Young's modulus of lead or component at solder joint: 1.279E07 psi

THERMAL CONDITIONS

Number	Temperature C		Dwell min.		Cycles	Name
	Hot	Cold	Hot	Cold		
1	100.0	0.0	5.0	5.0	72.000 CPD	ATC

Note: F = Fixed cycles; CPD = Cycles Per Day for variable type cycles

DESIGN LIFE and STATISTICAL PARAMETERS
Product design life: 5.000 Years
2P Weibull shape parameter (beta): 4.100
3P Weibull ratio: failure free time / characteristic life: 0.500

Table B.2: SRS Model Input Data for 540 I/O EBGA (0.75 mm BT, double reflow) on FR-4.

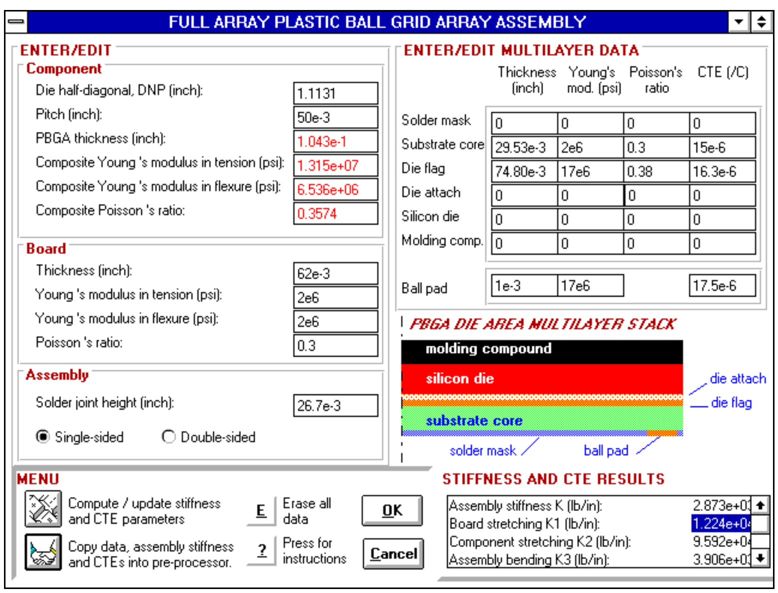

Figure B.2: EBGA540 (0.75 mm BT, double reflow): "PBGA" component window for calculation of assembly stiffness parameter and component effective CTE.

540 I/O EBGA, 1 mm BT, "single reflow"

INPUT OF SOLDER RELIABILITY SOLUTIONS PROGRAM SRS file name: EBGA540S.SRS Date: 04/03/2000 11:21:43 AM	SUBSTRATE DATA Substrate material: FR-4 Effective in-plane CTE in diagonal direction of component: 1.679E-05 /deg.C Young's modulus in tension: 2.000E06 psi Thickness: 6.200E-02 inch
PROJECT Title: SBGA540 'single side reflow', 1 mm BT- Lucent's test Notes: Analysis is at outermost corner joint. BT is 1 mm thick.	ASSEMBLY DATA Assembly stiffness: 3.038E03 lb/in Solder joint effective thickness: 1.810E-02 inch Solder joint crack area: 3.800E-04 sq.inch

COMPONENT DATA
Name: 560 I/O SBGA
Number of susceptible IOs: 12

Global Mismatch Parameters:
Distance to Neutral Point, DNP: 1.113E00 inch
Effective CTE: 1.579E-05 /deg.C

Local Mismatch Parameters:
Thickness of lead or component at solder joint: 1.152E-01 inch
Effective CTE of lead or component at solder joint: 1.624E-05 /deg.C
Effective Young's modulus of lead or component at solder joint: 1.187E07 psi

THERMAL CONDITIONS

Number	Temperature C		Dwell min.		Cycles	Name
	Hot	Cold	Hot	Cold		
1	100.0	0.0	5.0	5.0	72.000 CPD	ATC

Note: F = Fixed cycles; CPD = Cycles Per Day for variable type cycles

DESIGN LIFE and STATISTICAL PARAMETERS
Product design life: 5.000 Years
2P Weibull shape parameter (beta): 4.900
3P Weibull ratio: failure free time / characteristic life: 0.500

Table B.3: SRS Model Input Data for 540 I/O EBGA (1 mm BT, single reflow) on FR-4.

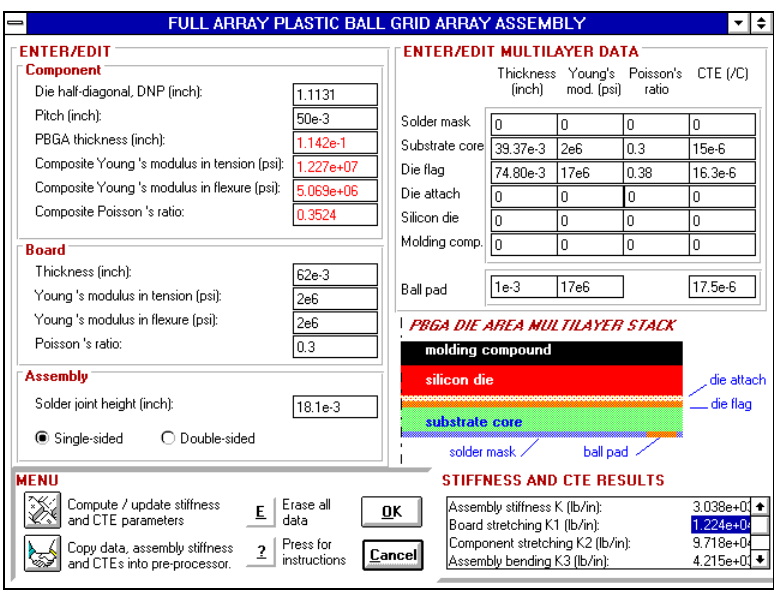

Figure B.3: EBGA540 (1 mm BT, single reflow): "PBGA" component window for calculation of assembly stiffness parameter and component effective CTE.

540 I/O EBGA, 1 mm BT, "double reflow"

INPUT OF SOLDER RELIABILITY SOLUTIONS PROGRAM

SRS file name: EBGA540D.SRS
Date: 04/03/2000 11:24:20 AM

SUBSTRATE DATA
Substrate material: FR-4
Effective in-plane CTE in diagonal direction of component: 1.679E-05 /deg.C
Young's modulus in tension: 2.000E06 psi
Thickness: 6.200E-02 inch

PROJECT
Title: SBGA540 'double side reflow', 1 mm BT- Lucent's test
Notes:
Analysis is at outermost corner joint. BT is 1 mm thick.

ASSEMBLY DATA
Assembly stiffness: 2.709E03 lb/in
Solder joint effective thickness: 2.670E-02 inch
Solder joint crack area: 3.800E-04 sq.inch

COMPONENT DATA
Name: 560 I/O SBGA
Number of susceptible IOs: 12

Global Mismatch Parameters:
Distance to Neutral Point, DNP: 1.113E00 inch
Effective CTE: 1.579E-05 /deg.C

Local Mismatch Parameters:
Thickness of lead or component at solder joint: 1.152E-01 inch
Effective CTE of lead or component at solder joint: 1.624E-05 /deg.C
Effective Young's modulus of lead or component at solder joint: 1.187E07 psi

THERMAL CONDITIONS

Number	Temperature C		Dwell min.		Cycles	Name
	Hot	Cold	Hot	Cold		
1	100.0	0.0	5.0	5.0	72.000 CPD	ATC

Note: F = Fixed cycles; CPD = Cycles Per Day for variable type cycles

DESIGN LIFE and STATISTICAL PARAMETERS
Product design life: 5.000 Years
2P Weibull shape parameter (beta): 4.600
3P Weibull ratio: failure free time / characteristic life: 0.500

Table B.4: SRS Model Input Data for 540 I/O EBGA (1 mm BT, double reflow) on FR-4.

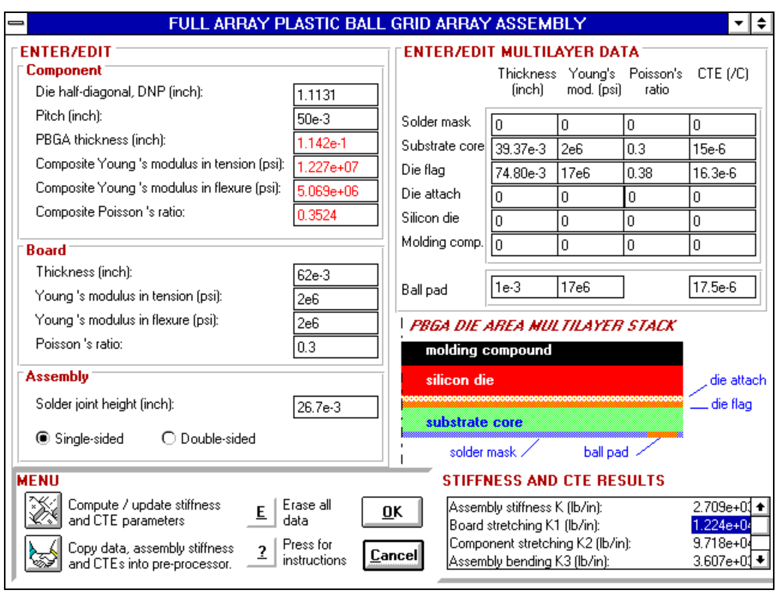

Figure B.4: EBGA540 (1 mm BT, double reflow): "PBGA" component window for calculation of assembly stiffness parameter and component effective CTE.