CORFIN INDUSTRIES
ELECTRONICS MANUFACTURING SOLUTIONS
Preventing Catastrophic Failures in Mission Critical Systems

Corfin Industries – Texas Operations: BGA Re-Balling Qualification

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Contacts*:*

Nathan R Draney – Engineering Manager	email: ndraney@corfin.com
Jamie Houle – Sr. Operations Manager	email: jhoule@corfin.com
Gregory S Berry – General Manager, Round Rock Operations	email: gberry@corfin.com
Keith Bentley – Quality Assurance Manager	email: kbentley@corfin.com
Paul Davis – Quality Assurance Engineer	email: pdavis@corfin.com
Don Tyler – President	email: dtyler@corfin.com

Executive Summary:

Corfin Industries continues to lead the industry providing Robotic Hot Solder Dip (RHSD) and BGA re-balling methods that have been preventing catastrophic failure in mission and life critical systems for over 25 years. To satisfy the high growth rate of BGA re-balling and ensure the highest levels of technological advancements, Corfin Industries has established the Round Rock (TX) facility (Texas Operations) as the Center of Excellence for BGA re-balling. Corfin's Texas Operations is ISO 9001 and AS9100 registered serving markets in the Military, Aerospace, Medical and other High-Tech sectors with a specialization in High Reliability. To verify the highest level of quality and competency in its services, Corfin conducted an internal qualification of the Texas Operations BGA re-balling process. This qualification followed the IEC/TS 62647-4 Process Management for Avionics Aerospace and Defense Electronic Systems Containing Lead-Free Solder Part 4: Ball Grid Array (BGA) Re-Balling qualification test methods. All qualification requirements were met.

Qualification Approach:

Many industry BGA re-balling facilities limit qualification to X-Ray and/or Scanning Acoustic Microscopy (SAM) to check for negative impact to internal structures. Although this is more cost effective and a much quicker approach, Corfin built the Texas Operations BGA re-balling qualification plan upon IEC/TS 62647-4 qualification test methods to ensure total industry compliance was achieved. Several additional tests were added to the standard IEC/TS 62647-4 qualification tests. Additional visual inspections during pre-processing and post de-balling were added to document any variation in the as received condition from the component vendors prior to the re-balling process. A pre-process ionic cleanliness was added to ensure any incoming contamination could be addressed prior to the start of the qualification lots. In addition to the extra visual and ionic testing, there is recognition that the key to a stable process is the level of automation control. This additional testing was performed to ensure unknown variables were not introduced to the testing and to validate process controls; see Table 1 Pre-Process Qualification Testing Results and Table 2 Post Process Qualification Results.

Table 1: Pre-Process Qualification Testing Results

Test Description	IEC/TS 62647-4 Method	Test Provider/Location	Results
*Pre-process Visual Inspection	100	Corfin New Hampshire	PASS
Pre-process XRF Testing	1200	Corfin New Hampshire	PASS
Pre-process SAM Testing	300	AcousTech	PASS
*Pre-process Cleanliness Testing	500	Corfin New Hampshire	PASS
*Pre-ship Visual Inspection	100	Corfin New Hampshire	PASS
Pre-process Inspection	100	Corfin Texas Operations	PASS

***Testing performed in addition to IEC/TS 62647-4 qualification requirements**

Table 2: De-Ball, Re-Ball and Post-Process Qualification Testing Results

Test Description	IEC/TS 62647-4 Method	Test Provider/Location	Results
*Post De-ball Visual Inspection	100	Corfin Texas Operations	PASS
Post Re-ball Visual Inspection	100	Corfin Texas Operations	PASS
Post Re-ball X-Ray Void Testing	1100	Corfin Texas Operations	PASS
Post Re-ball Cleanliness Testing	500	Corfin New Hampshire	PASS
Post Re-ball SAM Testing	300	AcousTech	PASS
Post Re-ball DPA Testing	1000	Advanced MicroAnalytical	PASS
Post Re-ball XRF Testing	1200	Corfin New Hampshire	PASS
Post Re-balling Ball Shear Testing	1300	Advanced MicroAnalytical	PASS
Post Re-balling Solderability Testing	600	Corfin New Hampshire	PASS

***Testing performed in addition to IEC/TS 62647-4 qualification requirements**

A more common practice in industry is to run a single production lot for process qualification. Corfin increased this industry minimum practice to three production lots, selecting different component geometries for a more diverse representation of industry requirements, process stability and repeatability; see Table 3 Process Logs & Associated Component ID.

Table 3: Process Lots & Associated Component ID

Process Lot & CPA	Component Type	Make From ID#	Make To ID#
82309-01, 23278	64 ucBGA	LCMXO2-256HC-4UMG64C	220-1427-ND
82329-01, 23282	324 UBGA	10M02SCU324C8G	544-3471-ND
82331-01, 23286	484 sPBGA	AM3505AZER	296-39681-ND

Processing:

De-Balling

The industry use of de-balling is most commonly performed to remove the existing component manufacturer's sphere, so the component can be re-populated; most commonly replaced with SnPb. In the case of all three lots processed for this qualification, the de-balling removed Pb-free spheres. There are several industry methods used for de-balling. Solder wicking, vacuum soldering, solder pot immersion, and dynamic solder wave are the most common methods, and all are allowed by IEC/TS 62647-4. That being the case, any de-balling process must not scratch the pads or damage the solder mask but must remove all the original alloy. Failure to completely remove the original alloy can then cause reliability concerns such as joint weakness and tin whisker growth. These reliability issues can readily result in catastrophic failures in mission critical systems.

Understanding the high risk associated with manual de-balling methods, Corfin New Hampshire and Corfin Texas Operations utilize state of the art fully automated Robotic Hot Solder Dip (RHSD) systems for all de-balling. These RHSD systems are the result of 30 years of research presenting components in an extremely controlled, precise and repeatable process to the integrated flux, preheat, dynamic solder wave, water rinse and dry. These systems are capable of motor control to ±0.1in/sec, pre-heater control of ±3°C, ±0.010 control within the manufactures' specific gravity, solder wave temperature control of ±1°C, and hot water wash control of ±3°C. Corfin's RHSD equipment are the only systems qualified by the "Final Report on the Transformational Manufacturing Technology Initiative (TMTI) ManTech Research Project S1057: Tin Whisker Mitigation - The Use of Robotic Solder Dipping to Replace Electronic Part Surfaces Finishes of Pure Tin With A Tin-Lead Finish" project performed with CALCE/Raytheon. This advanced level of automation controls ensures the complete removal and replacement of Pb-free alloys on each and every component. De-ball process verification to IEC/TS standards were performed as part of the qualification to ensure the critical controls relative to the flux, pre-heat, dynamic solderwave, clean and dry steps of the process complied.

Re-balling

Plastic body electronic components are built robust, but care must be taken when exposing to thermal events such as de-balling and re-balling. A general approach is to develop a "one size fits all" de-ball and re-ball reflow profile. Corfin does not follow this approach as experience has shown that there can be thermal sensitive differences between component manufacturers' in which case the "one size fits all" reflow could cause damage to the component. Corfin Engineering reviews all new component manufacturers' data sheets and compares reflow requirements against a vast internal library of component specific reflow profiles to ensure the perfect fit for the specific component. All new components require a reflow profile to be generated in which Corfin practices JEP140 thermal couple methods to ensure the highest accuracy and repeatability in thermal profile validation.

De-balled components are re-balled with customer specified spheres being held in place by component specific tooling/stencils designed by Corfin Engineering. After stencil fitting and sphere population, the components are reflowed in the fully automated systems guaranteeing critical thermal control and stability of process. As with the de-balling of these qualification lots, Corfin added a process verification to IEC/TS standard to ensure the critical controls relative to the re-balling process complied.

Testing:

Visual Inspection (IEC/TS 62647-4 Method 100)
Corfin's New Hampshire Operations coordinated the purchase of the three qualification lots/components. These lots were received at the Corfin New Hampshire Operations and underwent incoming inspection per standard Corfin operating procedures. Understanding that many variables can be introduced during shipping and unpacking (FOD, corrosion, physical damage, etc.), Corfin performs a 100% visual inspection of all lots rather than blindly loading as received components into production as commonly practiced by many industry re-balling providers. This inspection is performed by skilled operators trained and proficient to JEDEC JESD22-B101 standards. This incoming inspection is to identify any incoming component defects that could impact the quality and repeatability of the automated BGA de-balling and re-balling process. The intent of Visual Inspection Method 100 is to identify general issues, solder ball defects and package body/lid defects. This same level of inspection was performed during the required pre and post re-ball processing steps and during the three additional inspections. Many observations were recorded throughout the various inspections as the three qualifications lots processed, with the results being all components processed through de-ball and re-ball in this qualification passed visual inspection per Method 100 JEDEC JESD22-B101. These details can be reviewed in Section 1 of Appendix A.

XRF (IEC/TS 62647-4 Method 1200) & Ionic Cleanliness (IEC/TS 62647-4 Method 500)
Corfin New Hampshire has internal X-ray fluorescence (XRF) capabilities that meet JEDEC JESD213 requirements. This testing is crucial as it provides critical solder ball composition information ensuring that the removal and replacement of Pb-free with SnPb alloys. Corfin New Hampshire follows industry standards in the daily use/testing and calibration of the XRF systems. All pre and post XRF testing of the qualification lots resulted in passing results per JEDEC JESD213.

Corfin New Hampshire also has ionic cleanliness testing capability. This system/process meets IPC-TM-650-2.3.25 Resistivity of Solvent Extract (ROSE) requirements of 10µg/in^2 or 1.56µg/cm^2 testing limits. This testing ensures that components are clean of any fluxes that may be used during the de-balling and re-balling process. This testing was also performed pre-processing to ensure that no incoming contamination would negatively impact the qualification processing. All sample tests pre and post processing passed the IPC-TM-650-2.3.25 requirements. All ionic cleanliness testing results are available for review in Section 2 of Appendix A.

X-ray Void (IEC/TS 62647-4 Method 1100)
Voids in solder joints is a common occurrence in the SMT industry. Several factors can contribute or cause voids in solder joints with the most common being residual flux becoming entrapped during the reflow process. It is the amount/size of voids in solder joints that determines whether further processing issues and/or reliability concerns are warranted. For this purpose, X-ray Void testing is performed to determine if voiding levels are acceptable. IEC/TS 62647-4 Method 1100 references IPC J-STD-001 in performing this testing. Corfin Texas Operations utilized its own internal X-ray void testing capability and performed this test on all qualification lots. All three lots passed with acceptable voiding criteria. The detailed results can be observed in Section 3 of the Appendix A.

Scanning Acoustic Microscopy (IEC/TS 62647-4 Method 300)
Visual inspection is used to determine external package conditions, but internal component inspection requires X-ray, cross sectioning or SAM methods. Corfin has a long history of using SAM to verify de-balling and re-balling has industry acceptable impact to internal package structures. IEC/TS 62647-4 method 300 refers to IPC/JEDEC J-STD-020 and IPC/JEDEC J-STD-035 for the requirements of this testing. To ensure compliance to these requirements, Corfin partnered with AcousTech Inc., a well known and trusted SAM analysis provider. AcousTech performed pre and post process scans and found no internal package delamination progression that would fail criteria. The detailed SAM analysis can be found in Section 4 of Appendix A.

DPA (IEC/TS 62647-4 Method 1000)
Destructive physical analysis (DPA) incorporates various test methods under MIL-STD-883 Method 5009.1. The intent of DPA is to ensure that the component package construction is not compromised because of stresses caused by various manufacturing processing. It is common for many re-balling providers to stop short of DPA testing, relying solely on X-ray and/or SAM testing for qualification purposes. Corfin has always supported and participated in the development and use of industry standard testing. MIL-STD-883K Method 5009.1 Testing 3.4.1 External Visual was applied to all three qualification lots. This external visual testing is equal to Corfin's visual testing but understanding the value of an unbiased third-party testing, Corfin partnered with Advanced MicroAnalytical to have post processing visual inspection completed. Advanced MicroAnalytical performed this testing and found no conditions that would result in failure. The detailed testing results can be found in Section 5 of Appendix A.

Solderability (IEC/TS 62647-4 Method 600) & Ball Shear (IEC/TS 62647-4 Method 1300)
The IEC/TS 62647-4 Method 1300 Ball Shear references JEDEC JESD22-B117 for testing requirements. Test samples were sent to Advanced MicroAnalytical. The testing was completed, and the force and type of failure was documented. All samples passed the testing requirements. The details of both the solderability and ball shear testing can be found in Section 5 of Appendix A.

The final critical tests are that of solderability and ball shear. These tests are intended to ensure that the re-balled component will reflow correctly in the customers' manufacturing process and then perform reliably relative to the solder joint integrity. Corfin New Hampshire performed the IEC/TS 62647-4 Method 600 references IPC J-STD-002, Test S Solderability of all three qualification lots. This testing is performed by printing solder paste on a ceramic test substrate, placing spheres using the component specific stencil, and reflow. A 10x visual inspection is then performed to ensure the solder joints are continuous and free from defects. All samples tested passed the industry requirements. The details of the solderability testing can be found in Section 6 of Appendix A.

Conclusion:

Corfin Texas Operations' automated re-balling process is a reliable solution to resolve the risk of Pb-free/SnPb solder joint reliability concerns. This qualification effort ensures compliance to Corfin Industries standards and to key industry standards. This qualification was based upon the IEC/TS 62647-4 Process Management for Avionics Aerospace and Defense Electronic Systems Containing Lead-Free Solder Part 4: Ball Grid Array (BGA) Re-Balling qualification test methods. Additional testing (inspections, pre-process ionic cleanliness and pre-process XRF) was performed by Corfin to better understand and document processing variables. All three qualification lots processed met or exceeded Corfin's internal standards and subsequent industry standards. Both the Corfin New Hampshire and Texas Operations' facilities meet and exceed industry standards and should be considered as the industry leaders in quality and process control for any de-ball/re-ball services.

APPENDIX A:

Section 1: *Visual Inspection (IEC/TS 62647-4 Method 100)*

***Pre-process visual inspection at Corfin's New Hampshire Operations**

Production Lot#	QTY Good:	QTY re-work:	QTY Scrap:	Defect Code
82309-01	10	0	0	NA
82329-01	10	0	0	NA
82331-01	10	0	0	NA

***Testing performed in addition to IEC/TS 62647-4 qualification requirements**

***Pre-ship Visual Inspection at New Hampshire Operations**

Production Lot#	QTY Good:	QTY re-work:	QTY Scrap:	Defect Code
82309-01	10	0	0	NA
82329-01	10	0	0	NA
82331-01	10	0	0	NA

***Testing performed in addition to IEC/TS 62647-4 qualification requirements**

Pre-process Inspection at Corfin Texas Operations

Production Lot#	QTY Good:	QTY re-work:	QTY Scrap:	Defect Code
82309-01	10	0	0	NA
82329-01	10	0	0	NA
82331-01	10	0	0	NA

***Post De-ball Visual Inspection at Corfin Texas Operations**

Production Lot#	QTY Good:	QTY re-work:	QTY Scrap:	Defect Code
82309-01	10	0	0	NA
82329-01	10	0	0	NA
82331-01	10	1	1	7595

***Testing performed in addition to IEC/TS 62647-4 qualification requirements**
Note: One part used for process set-up

Post Re-ball Visual Inspection at Corfin Texas Operations

Production Lot#	QTY Good:	QTY re-work:	QTY Scrap:	Defect Code
82309-01	10	0	0	NA
82329-01	10	0	0	NA
82331-01	9	0	0	NA

Section 2: *XRF (IEC/TS 62647-4 Method 1200) & Ionic Cleanliness (IEC/TS 62647-4 Method 500)*

Corfin New Hampshire Operations XRF & Ionic Cleanliness Analysis for Lot# 82309-01

Pre De-balling		Post Re-balling		
Reading:	Pb%	Reading:	Sn %	Pb%
1	0	1	62	38
2	0	2	68	32
3	0	3	61	39
4	0	4	62	38
5	0	5	63	37
6	0	6	68	32
7	0	7	63	37
8	0	8	62	38
9	0	9	61	39

Pre De-balling			
Device No.:	Device Lot Code	Result	µg/sq of NaCl equivalent
1	1205	PASS	< 0.01
2	1205	PASS	< 0.01
3	1205	PASS	< 0.01
4	1205	PASS	< 0.01
5	1205	PASS	< 0.01

Post Re-balling			
Device No.:	Device Lot Code	Result	µg/sq of NaCl equivalent
1	1205	PASS	< 0.01
2	1205	PASS	0.55
3	1205	PASS	0.10
4	1205	PASS	0.03
5	1205	PASS	< 0.01

Corfin New Hampshire Operations XRF & Ionic Cleanliness Analysis for Lot# 82329-01

Pre De-balling		Post Re-balling		
Reading:	**Pb%**	**Reading:**	**Sn %**	**Pb%**
1	0	1	61	39
2	0	2	59	41
3	0	3	62	38
4	0	4	61	39
5	0	5	61	39
6	0	6	62	38
7	0	7	64	36
8	0	8	62	38
9	0	9	62	38

Pre De-balling			
Device No.:	**Device Lot Code**	**Result**	**µg/sq of NaCl equivalent**
1	1813	PASS	0.21
2	1813	PASS	< 0.01
3	1813	PASS	0.01
4	1813	PASS	0.04
5	1813	PASS	0.09

Post Re-balling			
Device No.:	**Device Lot Code**	**Result**	**µg/sq of NaCl equivalent**
1	1813	PASS	0.09
2	1813	PASS	< 0.01
3	1813	PASS	1.14
4	1813	PASS	0.49
5	1813	PASS	0.23

Corfin New Hampshire Operations XRF & Ionic Cleanliness Analysis for Lot# 82331-01

Pre De-balling		Post Re-balling		
Reading:	**Pb%**	**Reading:**	**Sn %**	**Pb%**
1	0	1	64	36
2	0	2	62	38
3	0	3	61	39
4	0	4	64	36
5	0	5	63	37
6	0	6	64	36
7	0	7	62	38
8	0	8	62	38
9	0	9	62	38

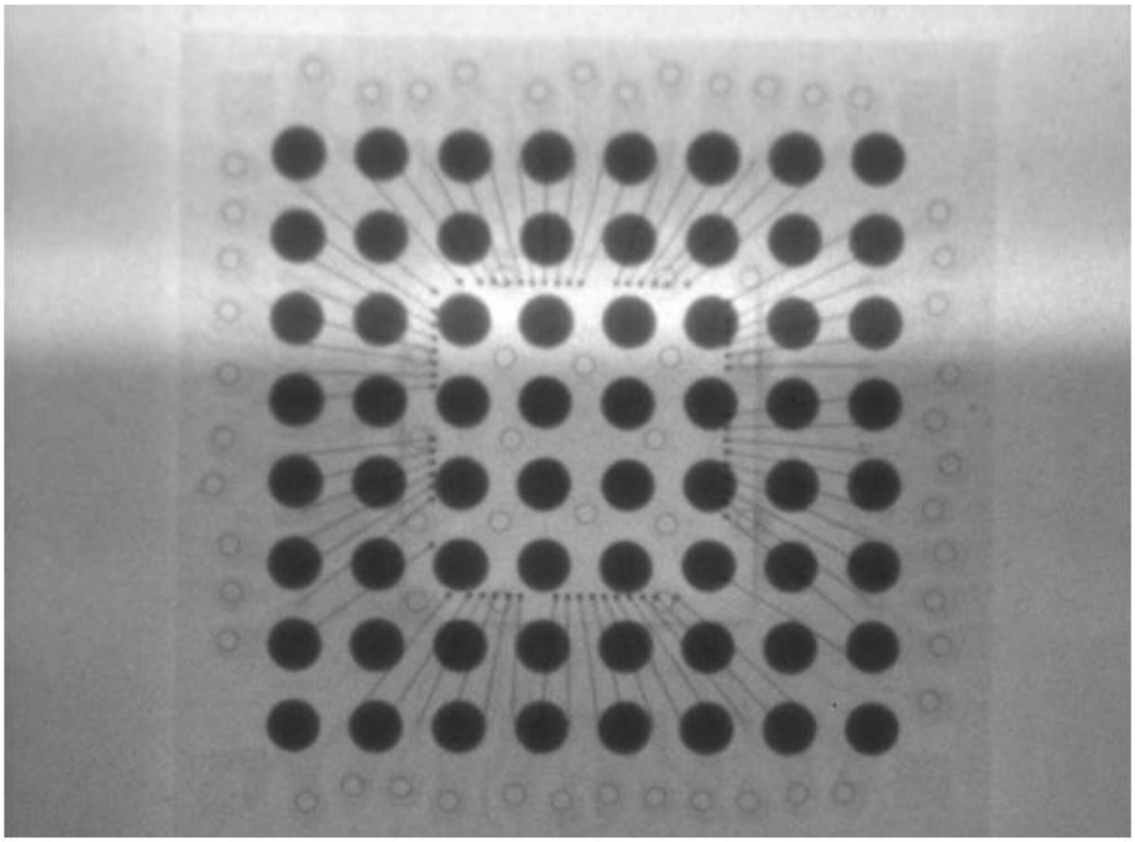
Pre De-balling			
Device No.:	**Device Lot Code**	**Result**	**µg/sq of NaCl equivalent**
1	N/A	PASS	0.04
2	N/A	PASS	< 0.01
3	N/A	PASS	0.18
4	N/A	PASS	0.01
5	N/A	PASS	< 0.01

Post Re-balling			
Device No.:	**Device Lot Code**	**Result**	**µg/sq of NaCl equivalent**
1	N/A	PASS	0.25
2	N/A	PASS	0.14
3	N/A	PASS	0.19
4	N/A	PASS	0.26
5	N/A	PASS	0.19

Section 3: *X-ray Void (IEC/TS 62647-4 Method 1100)*

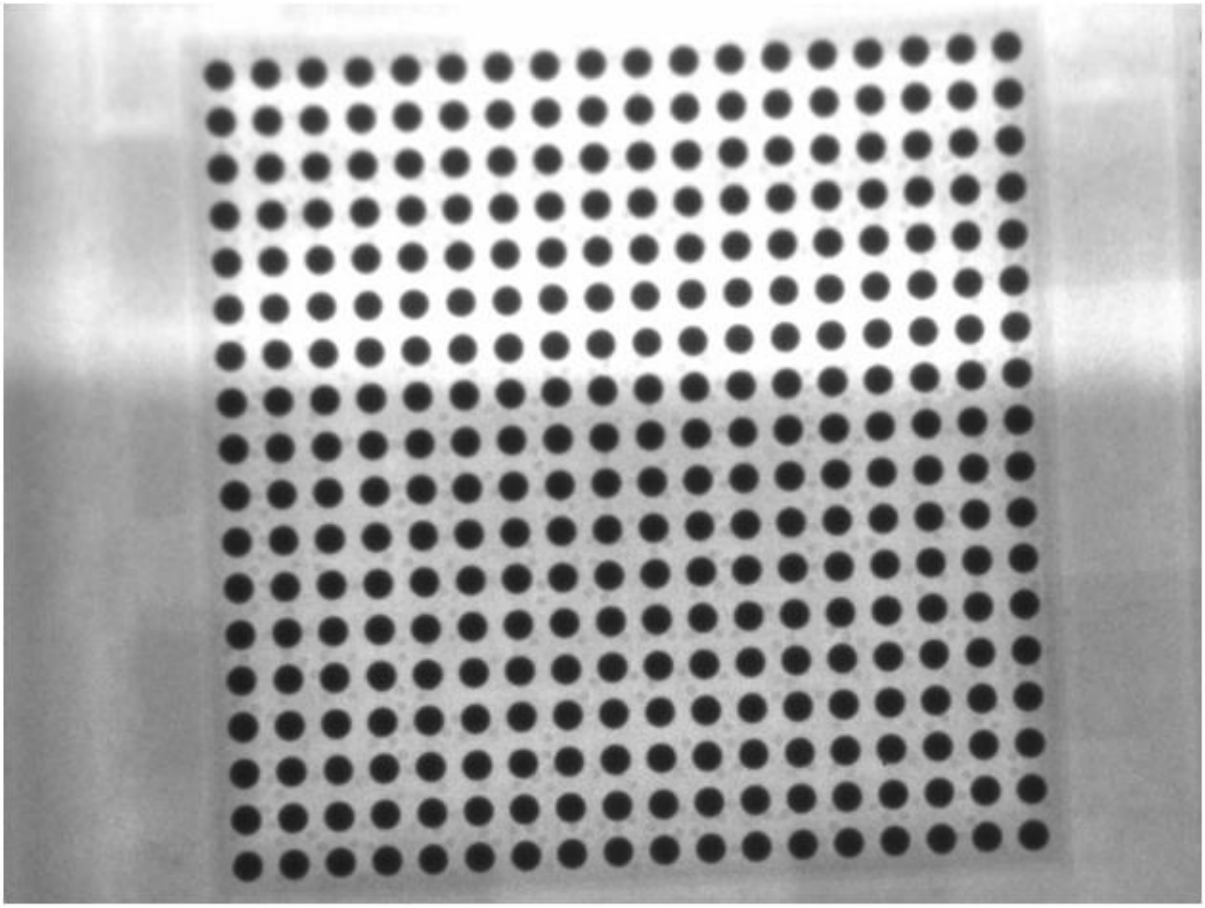
Corfin Texas Operations X-ray Void Analysis for Lot# 82309-01

Sample Identification 82309-01, 64 ucBGA		
Parameter	**Accept**	**Reject**
Voids in Solder Balls	**10**	**0**



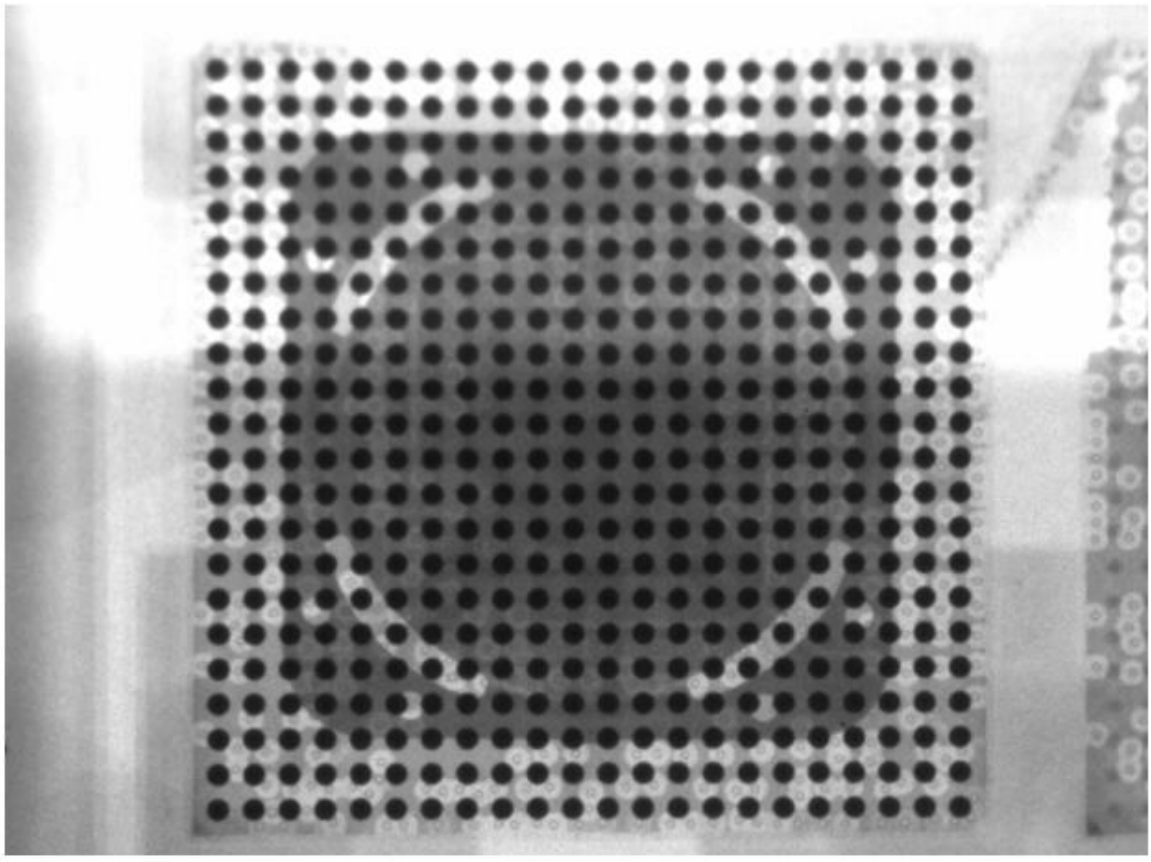
Corfin Texas Operations X-ray Void Analysis for Lot# 82329-01

Sample Identification 82329-01, 324 UBGA		
Parameter	**Accept**	**Reject**
Voids in Solder Balls	**10**	**0**



Corfin Texas Operations X-ray Void Analysis for Lot# 82331-01

Sample Identification 82331-01, 484 sPBGA		
Parameter	**Accept**	**Reject**
Voids in Solder Balls	**9**	**0**



Section 4: *Scanning Acoustic Microscopy (IEC/TS 62647-4 Method 300)*

AcousTech Job# 229-1044 Pre & Post Results for Lot# 82309-01

S/N	PRE				POST			
	Die scan	Substrate scan	Through-Transmission	PASS	Die scan	Substrate scan	Through-transmission	PASS
1	✓	✓	✓	Y	✓	✓	✓	Y
2	✓	✓	✓	Y	✓	✓	✓	Y
3	✓	✓	✓	Y	✓	✓	✓	Y
4	✓	✓	✓	Y	✓	✓	✓	Y
5	✓	✓	✓	Y	✓	✓	✓	Y
6	✓	✓	✓	Y	✓	✓	✓	Y
7	✓	✓	✓	Y	✓	✓	✓	Y
8	✓	✓	✓	Y	✓	✓	✓	Y
9	✓	✓	✓	Y	✓	✓	✓	Y
10	✓	✓	✓	Y	✓	✓	✓	Y

AcousTech Job# 229-1045 Pre & Post Results for Lot# 82329-01

S/N	PRE				POST			
	Die scan	Substrate Scan	Through-Transmission	PASS	Die scan	Substrate Scan	Through-transmission	PASS
1	✓	✓	✓	Y	✓	✓	✓	Y
2	✓	✓	✓	Y	✓	✓	✓	Y
3	✓	✓	✓	Y	✓	✓	✓	Y
4	✓	✓	✓	Y	✓	✓	✓	Y
5	✓	✓	✓	Y	✓	✓	✓	Y
6	✓	✓	✓	Y	✓	✓	✓	Y
7	✓	✓	✓	Y	✓	✓	✓	Y
8	✓	✓	✓	Y	✓	✓	✓	Y
9	✓	✓	✓	Y	✓	✓	✓	Y
10	✓	✓	✓	Y	✓	✓	✓	Y

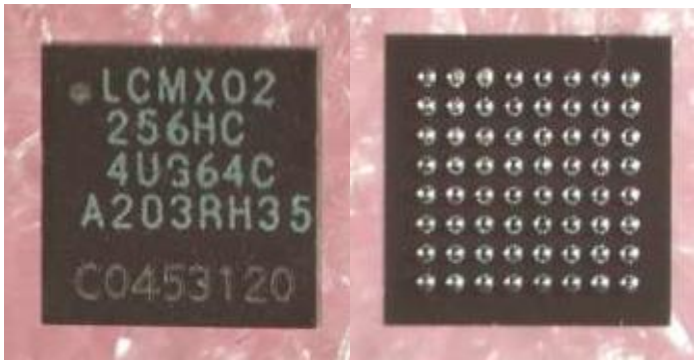
AcousTech Job# 229-1046 Pre & Post Results for Lot# 82331-01

S/N	PRE			POST		
	Die scan	Through-Transmission	PASS	Die scan	Through-transmission	PASS
1	✓	✓	Y	✓	✓	Y
2	✓	✓	Y			
3	✓	✓	Y	✓	✓	Y
4	✓	✓	Y	✓	✓	Y
5	✓	✓	Y	✓	✓	Y
6	✓	✓	Y	✓	✓	Y
7	✓	✓	Y	✓	✓	Y
8	✓	✓	Y	✓	✓	Y
9	✓	✓	Y	✓	✓	Y
10	✓	✓	Y	✓	✓	Y

Note: S/N #2 part used for process set-up

Section 5: *DPA (IEC/TS 62647-4 Method 1000) & Ball Shear (IEC/TS 62647-4 Method 1300)*

Advanced MicroAnalytical Job# 231900080; Visual Inspection for Lot# 82309-01



DPA External Visual Inspection per Mil-Std-883K, Method 5009.12

Sample Identification	Altera, 10M02SCU324C8G, D/C: 1813					
Parameter	Accept			Reject		
	Device 1			Device 1		
Section 3.3.1 General						
3.3.1a Illegible marking, marking content or placement	✔					
3.3.1b Presence of Secondary coating material that visually obscures a seal area	N/A					
3.3.1c Evidence of any nonconformance with detail drawing, procurement document or absence of required feature	N/A					
Section 3.3.2 Foreign/Displaced material						
3.3.2a Braze material flow or other foreign material that reduces isolation between lead or braze pads to less than 50% of separation.	N/A					
3.3.2b Leads or terminations not free of foreign material	✔					
Section 3.3.3 Construction Defects						
3.3.3a Protrusions on Bottom that extends beyond seating plane.	✔					
3.3.3b Protrusions (excluding glass run-out) on any other package surface exceeding lead thickness in height	✔					
3.3.3c Lid/Cover protrusions exceeding 25% of terminal width in height.	✔					
3.3.3d Metallization no intended by design that reduces isolation by 50% of pad separation	✔					
Section 3.3.4 Package Body/ Lid Finish						
3.3.4a Defective finish (peeling, flaking etc.)	✔					
3.3.4b Scratches, mars, idents that expose base metal	✔					

Advanced MicroAnalytical Job# 231900080; Visual Inspection for Lot# 82309-01

Parameter	Accept			Reject		
	Device 1			Device 1		
3.3.5 Leads						
3.3.5a/b Broken leads or terminals, misaligned or twisted more than 20 degrees	N/A					
3.3.5c Pits or depressions exceeding 25% of width or greater than 50% lead thickness	N/A					
3.3.5d Burrs exceeding height 50% greater than lead thickness	N/A					
3.3.5e Misalignment to braze pad >25% of lead	N/A					
3.3.5f Metallization bridging greater that 50% lead separation	N/A					
3.3.5g Braze material that increase lead > 1.5X lead thickness	N/A					
3.3.5h Scratches that expose base metal > 5% of lead surface area	N/A					
3.3.6 Ball/Column/Grid Array						
3.3.6a Nonconformance with design	N/A					
3.3.6b Off center/skewed exposing >20% of pad	✔					
3.3.6c Broken/twisted	✔					
3.3.6d Voids, holes, pits > than 15% diameter	✔					
3.3.6f/g/h Any cracks, peeling, flaking, blister or any burrs/bumps exceeding 20% diameter	✔					
3.3.3k Corrosion, crusting or residual flux, foreign material or adherent deposits	✔					
3.3.7 Package Body/lid – leaded devices						
3.3.7a Broken packages or cracks in package	N/A					
3.3.7b Chipping >0.06" with a depth >25% thickness of affected element (base, lids etc.)	N/A					
3.3.7c Voids >25% conductor width of external metal stripe.	N/A					
3.3.7d Cracks, delam, voids in multilayer package	N/A					

Advanced MicroAnalytical Job# 231900080; Visual Inspection for Lot# 82309-01

Parameter	Accept			Reject		
	Device 1			Device 1		
3.3.8 Package Body/lid – leadless devices						
3.3.8a Ceramic chipping>50% distance between terminals and >25% thickness affected element	N/A					
3.3.8b Cracks, Delam, separation or voiding on any package	✔					
3.3.8c Castellation to solder pad misalignment	N/A					
3.3.9 Glass seal						
3.3.9a Crazing of seal surface	N/A					
3.3.9b Circumferential crack exceeding single quadrant	N/A					
3.3.9c Radial cracks not originating at leads. Three or more extending beyond mid-point.	N/A					
3.3.9d Chip out deeper than meniscus plane	N/A					
3.3.9e Open bubbles >5 mils in diameter. For packages with glass filled header open bubbles >10 mils dia or an open bubbles > 5 mils situated closer than 10 mils to a lead. Strings or clusters of open bubbles > 2/3 distance between lead and package wall	N/A					
3.3.9f Subsurface bubbles or voids> 1/3 glass sealing area. Single bubble/void >2/3 distance of lead to package wall. Two in a line >2/3 distance case to pin. Interconnecting >2/3 distance pin to case.	N/A					
3.3.9g Negative meniscus at lead or body interface.	N/A					

Advanced MicroAnalytical Job# 231900080; Ball Shear for Lot# 82309-01

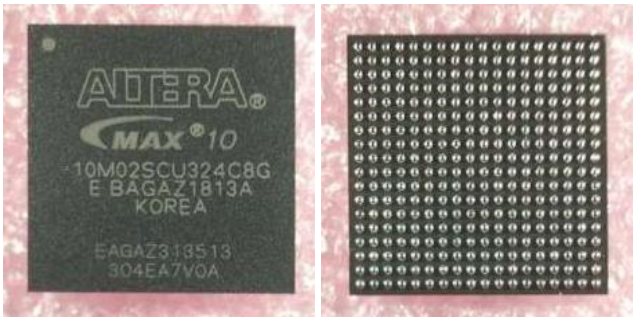
Table #1

Ball	Device 1	Failure Mode	Ball		Failure Mode
A1	102	1	1B	106	1
A2	99	1	1C	109	1
A3	107	1	1D	107	1
A4	100	1	1E	106	1
A5	107	1	1F	100	1
A6	107	1	1G	91	1
A7	106	1	1H	122	1
A8	109	1			
Min	**91**				
Max	**122**				
Average	**105.20**				
Std Dev	**6.710**				

Failure Mode	Description	Criteria
1	**Ductile:** solder ball fracture at or above the surface of the solder mask within the bulk of the solder material	Acceptable
2	**Pad Lift:** Solder pad lifts with solder ball	Rejectable
3	**Non-wet:** Solder ball lifts from pad and any portion of the pad top-surface plating is exposed	Rejectable
4	**Brittle:** The break is at the solder/intermetallic interface or intermetallic/base metal interface	Rejectable

Note: Acceptable/Rejectable criteria per IEC/TS 62647-4 Ball Shear (Method 1300)

Advanced MicroAnalytical Job# 231900079; Visual Inspection for Lot# 82329-01



DPA External Visual Inspection per Mil-Std-883K, Method 5009.12

Sample Identification	Altera, 10M02SCU324C8G, D/C: 1813					
Parameter	Accept			Reject		
	Device 1			Device 1		
Section 3.3.1 General						
3.3.1a Illegible marking, marking content or placement	✔					
3.3.1b Presence of Secondary coating material that visually obscures a seal area	N/A					
3.3.1c Evidence of any nonconformance with detail drawing, procurement document or absence of required feature	N/A					
Section 3.3.2 Foreign/Displaced material						
3.3.2a Braze material flow or other foreign material that reduces isolation between lead or braze pads to less than 50% of separation.	N/A					
3.3.2b Leads or terminations not free of foreign material	✔					
Section 3.3.3 Construction Defects						
3.3.3a Protrusions on Bottom that extends beyond seating plane.	✔					
3.3.3b Protrusions (excluding glass run-out) on any other package surface exceeding lead thickness in height	✔					
3.3.3c Lid/Cover protrusions exceeding 25% of terminal width in height.	✔					
3.3.3d Metallization no intended by design that reduces isolation by 50% of pad separation	✔					
Section 3.3.4 Package Body/ Lid Finish						
3.3.4a Defective finish (peeling, flaking etc.)	✔					
3.3.4b Scratches, mars, idents that expose base metal	✔					

Advanced MicroAnalytical Job# 231900079; Visual Inspection for Lot# 82329-01

Parameter	Accept			Reject		
	Device 1			Device 1		
3.3.5 Leads						
3.3.5a/b Broken leads or terminals, misaligned or twisted more than 20 degrees	N/A					
3.3.5c Pits or depressions exceeding 25% of width or greater than 50% lead thickness	N/A					
3.3.5d Burrs exceeding height 50% greater than lead thickness	N/A					
3.3.5e Misalignment to braze pad >25% of lead	N/A					
3.3.5f Metallization bridging greater that 50% lead separation	N/A					
3.3.5g Braze material that increase lead > 1.5X lead thickness	N/A					
3.3.5h Scratches that expose base metal > 5% of lead surface area	N/A					
3.3.6 Ball/Column/Grid Array						
3.3.6a Nonconformance with design	N/A					
3.3.6b Off center/skewed exposing >20% of pad	✔					
3.3.6c Broken/twisted	✔					
3.3.6d Voids, holes, pits > than 15% diameter	✔					
3.3.6f/g/h Any cracks, peeling, flaking, blister or any burrs/bumps exceeding 20% diameter	✔					
3.3.3k Corrosion, crusting or residual flux, foreign material or adherent deposits	✔					
3.3.7 Package Body/lid – leaded devices						
3.3.7a Broken packages or cracks in package	N/A					
3.3.7b Chipping >0.06" with a depth >25% thickness of affected element (base, lids etc.)	N/A					
3.3.7c Voids >25% conductor width of external metal stripe.	N/A					
3.3.7d Cracks, delam, voids in multilayer package	N/A					

Advanced MicroAnalytical Job# 231900079; Visual Inspection for Lot# 82329-01

Parameter	Accept			Reject		
	Device 1			Device 1		
3.3.8 Package Body/lid – leadless devices						
3.3.8a Ceramic chipping>50% distance between terminals and >25% thickness affected element	N/A					
3.3.8b Cracks, Delam, separation or voiding on any package	✔					
3.3.8c Castellation to solder pad misalignment	N/A					
3.3.9 Glass seal						
3.3.9a Crazing of seal surface	N/A					
3.3.9b Circumferential crack exceeding single quadrant	N/A					
3.3.9c Radial cracks not originating at leads. Three or more extending beyond mid-point.	N/A					
3.3.9d Chip out deeper than meniscus plane	N/A					
3.3.9e Open bubbles >5 mils in diameter. For packages with glass filled header open bubbles >10 mils dia or an open bubbles > 5 mils situated closer than 10 mils to a lead. Strings or clusters of open bubbles > 2/3 distance between lead and package wall	N/A					
3.3.9f Subsurface bubbles or voids> 1/3 glass sealing area. Single bubble/void >2/3 distance of lead to package wall. Two in a line >2/3 distance case to pin. Interconnecting >2/3 distance pin to case.	N/A					
3.3.9g Negative meniscus at lead or body interface.	N/A					

Advanced MicroAnalytical Job# 231900079; Ball Shear for Lot# 82329-01

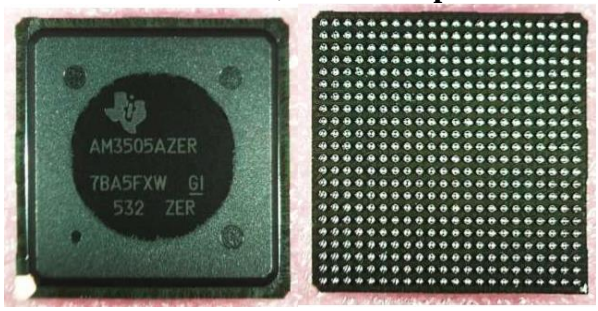
Table #1

Ball	Device 1	Failure Mode	Ball		Failure Mode
A1	466	1	18B	476	1
A2	450	1	18C	480	1
A3	482	1	18D	478	1
A4	489	1	18E	464	1
A5	473	1	18F	457	1
A6	459	1	18G	462	1
A7	466	1	18H	475	1
A8	471	1	18J	464	1
A9	471	1	18K	476	1
A10	424	1	18L	457	1
A11	480	1	18M	460	1
A12	478	1	18N	478	1
A13	410	1	18P	432	1
A14	469	1	18R	469	1
A15	475	1	18T	502	1
A16	476	1	18U	450	1
A17	476	1	18V	467	1
A18	491	1			
Min	**410**				
Max	**502**				
Average	**467.23**				
Std Dev	**17.984**				

Failure Mode	Description	Criteria
1	**Ductile:** solder ball fracture at or above the surface of the solder mask within the bulk of the solder material	Acceptable
2	**Pad Lift:** Solder pad lifts with solder ball	Rejectable
3	**Non-wet:** Solder ball lifts from pad and any portion of the pad top-surface plating is exposed	Rejectable
4	**Brittle:** The break is at the solder/intermetallic interface or intermetallic/base metal interface	Rejectable

Note: Acceptable/Rejectable criteria per IEC/TS 62647-4 Ball Shear (Method 1300)

Advanced MicroAnalytical Job# 231900078; Visual Inspection for Lot# 82331-01



DPA External Visual Inspection per Mil-Std-883K, Method 5009.12

Sample Identification	Altera, 10M02SCU324C8G, D/C: 1813					
Parameter	**Accept**			**Reject**		
	Device 1			**Device 1**		
Section 3.3.1 General						
3.3.1a Illegible marking, marking content or placement	✔					
3.3.1b Presence of Secondary coating material that visually obscures a seal area	N/A					
3.3.1c Evidence of any nonconformance with detail drawing, procurement document or absence of required feature	N/A					
Section 3.3.2 Foreign/Displaced material						
3.3.2a Braze material flow or other foreign material that reduces isolation between lead or braze pads to less than 50% of separation.	N/A					
3.3.2b Leads or terminations not free of foreign material	✔					
Section 3.3.3 Construction Defects						
3.3.3a Protrusions on Bottom that extends beyond seating plane.	✔					
3.3.3b Protrusions (excluding glass run-out) on any other package surface exceeding lead thickness in height	✔					
3.3.3c Lid/Cover protrusions exceeding 25% of terminal width in height.	✔					
3.3.3d Metallization no intended by design that reduces isolation by 50% of pad separation	✔					
Section 3.3.4 Package Body/ Lid Finish						
3.3.4a Defective finish (peeling, flaking etc.)	✔					
3.3.4b Scratches, mars, idents that expose base metal	✔					

Advanced MicroAnalytical Job# 231900078; Visual Inspection for Lot# 82331-01

Parameter	Accept			Reject		
	Device 1			Device 1		
3.3.5 Leads						
3.3.5a/b Broken leads or terminals, misaligned or twisted more than 20 degrees	N/A					
3.3.5c Pits or depressions exceeding 25% of width or greater than 50% lead thickness	N/A					
3.3.5d Burrs exceeding height 50% greater than lead thickness	N/A					
3.3.5e Misalignment to braze pad >25% of lead	N/A					
3.3.5f Metallization bridging greater that 50% lead separation	N/A					
3.3.5g Braze material that increase lead > 1.5X lead thickness	N/A					
3.3.5h Scratches that expose base metal > 5% of lead surface area	N/A					
3.3.6 Ball/Column/Grid Array						
3.3.6a Nonconformance with design	N/A					
3.3.6b Off center/skewed exposing >20% of pad	✔					
3.3.6c Broken/twisted	✔					
3.3.6d Voids, holes, pits > than 15% diameter	✔					
3.3.6f/g/h Any cracks, peeling, flaking, blister or any burrs/bumps exceeding 20% diameter	✔					
3.3.3k Corrosion, crusting or residual flux, foreign material or adherent deposits	✔					
3.3.7 Package Body/lid – leaded devices						
3.3.7a Broken packages or cracks in package	N/A					
3.3.7b Chipping >0.06" with a depth >25% thickness of affected element (base, lids etc.)	N/A					
3.3.7c Voids >25% conductor width of external metal stripe.	N/A					
3.3.7d Cracks, delam, voids in multilayer package	N/A					

Advanced MicroAnalytical Job# 231900078; Visual Inspection for Lot# 82331-01

Parameter	Accept			Reject		
	Device 1			Device 1		
3.3.8 Package Body/lid – leadless devices						
3.3.8a Ceramic chipping>50% distance between terminals and >25% thickness affected element	N/A					
3.3.8b Cracks, Delam, separation or voiding on any package	✔					
3.3.8c Castellation to solder pad misalignment	N/A					
3.3.9 Glass seal						
3.3.9a Crazing of seal surface	N/A					
3.3.9b Circumferential crack exceeding single quadrant	N/A					
3.3.9c Radial cracks not originating at leads. Three or more extending beyond mid-point.	N/A					
3.3.9d Chip out deeper than meniscus plane	N/A					
3.3.9e Open bubbles >5 mils in diameter. For packages with glass filled header open bubbles >10 mils dia or an open bubbles > 5 mils situated closer than 10 mils to a lead. Strings or clusters of open bubbles > 2/3 distance between lead and package wall	N/A					
3.3.9f Subsurface bubbles or voids> 1/3 glass sealing area. Single bubble/void >2/3 distance of lead to package wall. Two in a line >2/3 distance case to pin. Interconnecting >2/3 distance pin to case.	N/A					
3.3.9g Negative meniscus at lead or body interface.	N/A					

Advanced MicroAnalytical Job# 231900078; Ball Shear for Lot# 82331-01

Table #1

	Device 1	Failure Mode			Failure Mode
Ball			Ball		
12A	763	1	M1	768	1
12B	829	1	M2	768	1
12C	758	1	M3	804	1
12D	783	1	M4	822	1
12E	799	1	M5	835	1
12F	724	1	M6	810	1
12G	820	1	M7	840	1
12H	736	1	M8	776	1
12J	810	1	M9	810	1
12K	788	1	M10	815	1
12L	767	1	M11	801	1
12M	795	1	M13	790	1
12N	795	1	M14	862	1
12P	806	1	M15	820	1
12R	795	1	M16	810	1
12T	752	1	M17	810	1
12U	770	1	M18	758	1
12V	768	1	M19	826	1
12W	802	1	M20	790	1
12Y	847	1	M21	788	1
12AA	785	1	M22	788	1
12AB	765	1			
Min	**724**				
Max	**862**				
Average	**794.14**				
Std Dev	**29.334**				

Failure Mode	Description	Criteria
1	**Ductile:** solder ball fracture at or above the surface of the solder mask within the bulk of the solder material	Acceptable
2	**Pad Lift:** Solder pad lifts with solder ball	Rejectable
3	**Non-wet:** Solder ball lifts from pad and any portion of the pad top-surface plating is exposed	Rejectable
4	**Brittle:** The break is at the solder/intermetallic interface or intermetallic/base metal interface	Rejectable

Note: Acceptable/Rejectable criteria per IEC/TS 62647-4 Ball Shear (Method 1300)

Section 6: *Solderability (IEC/TS 62647-4 Method 600)*

Solderability Test at Corfin New Hampshire Operations

Production Lot#	QTY Good:	QTY re-work:	QTY Scrap:	Defect Code
82309-01	3	0	0	NA
82329-01	3	0	0	NA
82331-01	3	0	0	NA

REFERENCES:

1. International Electrotechnical Commission, Technical Standard for Process Management for Avionics Aerospace and Defense Electronic Systems Containing Lead-Free Solder, Std. IEC/TS 62647-4, Geneva, Switzerland, April 2018

2. Rollins, W., P., Pinsky, D., A., Minter, C., S., Toussaint, G., Das, D., Tyler, D., "Final Report on the Transformational Manufacturing Technology Initiative (TMTI) ManTech Research Project S1057: Tin Whisker Mitigation The Use of Robotic Solder Dipping to Replace Electronic Part Surfaces Finishes of Pure Tin With a Tin-Lead Finish", April 2006

3. JEDEC, Beaded Thermocouple Temperature Measurement of Semiconductor Packages, Std. JEP140, Arlington, VA, January 2015

4. JEDEC, Solid State Device Environmental Testing, Test Method B101 External Visual, Std. JESD22-B101C, Arlington, VA, October 2015

5. IPC, Test Methods Manual, Detection and Measurement of Ionizable Surface Contamination by Resistivity of Solvent Extract (ROSE), Std. IPC-TM-650-2.3.25, Bannockburn, IL, November 2012

6. IPC/JEDEC, Requirements for Soldered Electrical and Electronic Assemblies, Std. IPC J-STD-001, Bannockburn, IL, October 2017

7. IPC/JEDEC, Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices, Std. J-STD-020, Bannockburn, IL, December 2014

8. IPC/JEDEC, Acoustic Microscopy for Non-Hermetic Encapsulated Electronic Components, Std. J-STD-035, Bannockburn, IL, May 1999

9. Department of Defense Test Method Standard Microcircuits, Std. MIL-STD-883K, April 2016

10. IPC/JEDEC, Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires, Std. IPC J-STD-002, Bannockburn, IL, November 2017

11. JEDEC, Solid State Device Environmental Testing, Solder Ball Shear, Std. JESD22-B117, Arlington, VA, May 2014