April 4, 2014

Subject: Characterization Summary – Copper Bond Wire at Amkor Philippines

SUMMARY

Per PCN# 03A-14, this document summarizes the electrical characterization that supports an alternate qualified assembly and test site (Amkor Philippines) and alternate qualified material sets.

METHODOLOGY

The characterization focused on five items:

1) Assessment of critical Bill of Materials
2) Comparison of production yields
3) Assessment of Critical Parameters
4) SSO (Simultaneous Switching Output) Characteristics
5) SERDES performance (ECP3-150 only)

BILL OF MATERIALS

Product/Package combinations for characterization were chosen to represent a cross-section of the BOM (Bill of Material) changes specified in the PCN. The product/packages and the critical BOM components are:

Product/Pkg	ASEM Copper (Control)			AMKOR Copper (New)		
	Mold Compound	Wire/ Diameter	Die Attach	Mold Compound	Wire/ Diameter	Die Attach
LFE3-150EA/ 1156fpBGA	EMEG750SE	0.8mil Pd Coated Cu	ABLEBOND 2100A	Hitachi GE-110	0.8mil Pd Coated Cu	Ablebond 2300
LFXP2-17E/ 256ftBGA	EMEG750SE	0.8mil Pd Coated Cu	ABLEBOND 2100A	Hitachi GE-110	0.8mil Pd Coated Cu	Ablebond 2300
LFXP2-5E/ 144TQFP	EMEG700Y	0.8mil Pure Cu	Yizbond 8143	Sumitomo G700SY	0.8mil Pd Coated Cu	Ablebond 3230

Multiple lots of in various product/package combinations were built as part of the reliability qualification process for the AMKOR Copper BOM. Samples from the qual lots were characterized and compared to comparable lots processed with the released ASE Malaysia (ASEM) Copper BOM.

From an electrical viewpoint, the same wire diameter and same base material implies that electrical performance should be constant. Characterization was performed to confirm that assumption.

ASSEMBLY/ELECTRICAL TEST YIELDS

The first step in the characterization process is an analysis of process yields. Yield information is critical to gauge the manufacturability of a new package. As Lattice considers yield information proprietary, the yield information below is normalized with respect to the control material, which in this case is the existing ASEM Copper wire BOM.

LFE3-150	Assembly Yield		Electrical Test Yield	
	ASEM Copper (Control)	Amkor	ASEM Copper (Control)	Amkor
Normalized Yield	1.00	1.00	1.00	1.00

LFXP2-17E	Assembly Yield		Electrical Test Yield	
	ASEM Copper (Control)	Amkor	ASEM Copper (Control)	Amkor
Normalized Yield	1.00	0.98	1.00	0.97

LFXP2-5E	Assembly Yield		Electrical Test Yield	
	ASEM Copper (Control)	Amkor	ASEM Copper (Control)	Amkor
Normalized Yield	1.00	0.98	1.00	0.94

Lower electrical test yields on the LFXP2-5E were attributable to a test error. No other discernible differences in either assembly yield or electrical final test yields between ASEM and AMKOR copper assembly processes were noted.

CRITICAL PARAMETERS

For the purposes of this characterization, critical parameters are defined as speed and power. Samples of the qualification lots from AMKOR were tested at the same time as comparative product from ASEM. The tabulated statistics, Cpk values and histograms of the actual distributions are shown below.

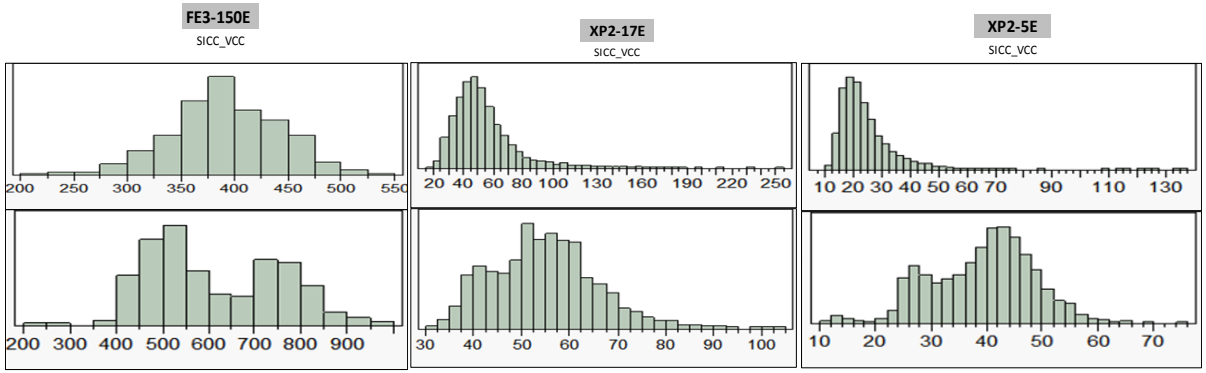
Note that Tpdcounter is a Built-in Self Test (BIST) routine that is correlated to datasheet parameters. Higher counts equate to faster devices.

Note that in most cases the Cpk of the Amkor material is actually better than the control units but the change is not significant and more a function of the sample sizes used. The critical parameters look normally distributed and do not point to any significant parametric difference between ASEM and AMKOR copper bond wire.

		Icc(mA)				
		N	Mean	Std	Spec	Cpk
LFE3-150EA	AMKOR Copper lot	704	391.73	49.04	2693	2.7
	ASEM Copper lot (control)	590	612.7	140.6	2693	1.5
LFXP2-17E	AMKOR Copper lot	1083	54.75	11.01	395	1.66
	ASEM Copper lot (control)	7349	53.1	20.71	395	0.9
LFXP2-5E	AMKOR Copper lot	1921	39.3	8.93	172	1.5
	ASEM Copper lot (control)	28435	23.5	8.08	172	1

ASE Cu

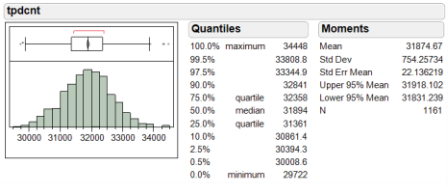
Amkor Cu

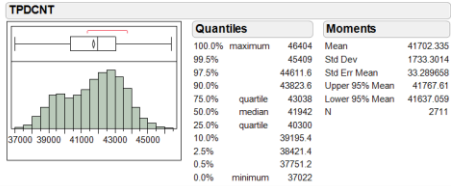


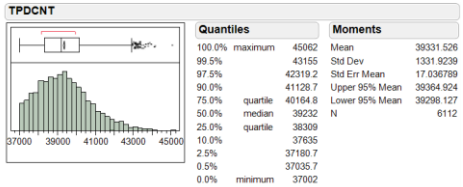
TPDCOUNT						
Product	**Group**	**N**	**Mean**	**Std**	**Spec**	**Cpk**
LFE3-150	**Amkor Copper**	698	31398	1043.9	26561	1.54
	ASEM Copper (control)	1161	31875	754.3	26561	2.35
LFXP2-17E	**Amkor Copper**	949	42040	1525.4	31630	2.27
	ASEM Copper (control)	2711	41702	1733.3	31630	1.94
LFXP2-5E	**Amkor Copper**	1686	40180	1158.3	32000	2.35
	ASEM Copper (control)	6112	39331	1331.0	32000	1.84

LFE3-150EA LFXP2-17E LFXP2-5E

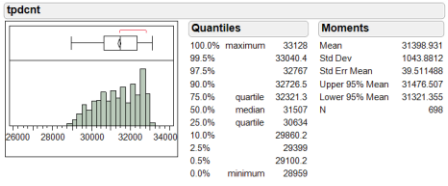
ASEM Cu

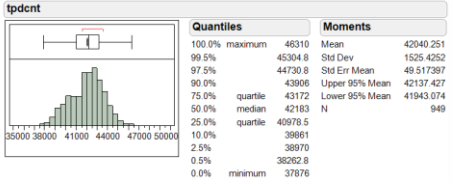


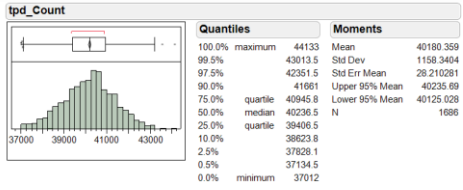




Amkor Cu







SIMULTANEOUS OUTPUT SWITCHING PERFORMANCE

Electrical characterization of a new assembly facility includes a check of Simultaneous Switching Output (SSO) performance. This characteristic is also referred to as Ground Bounce although it can affect both power and ground supply rails.

Different assembly site may have different process or tooling which can affect SSO performance. Since copper build in ASE Malaysia and Amkor have the same bond wire geometry (length and diameter), SSO results are expected to be comparable. A delta greater than 10% is considered significant.

			Ground Bounce		Output Disturb	
Product	**Material**		**Max (mV)**	**Min (mV)**	**Max (V)**	**Min (V)**
FE3-150EA-BFN1156	Amkor Cu		258	-130	1.93	1.448
	ASEM Cu Control		256	-126	1.942	1.486
		Delta	2	-4	-0.012	-0.038
		%Delta	0.8%	3.2%	-0.6%	-2.6%
LFXP2-17E-FTN256	Amkor Cu		222	-144	1.376	0.904
	ASEM Cu Control		244	-154	1.348	0.956
		Delta	-22	10	0.028	-0.052
		%Delta	-9.0%	-6.5%	2.1%	-5.4%
LFXP2-5E-TN144	Amkor Cu		332	-188	1.728	0.796
	ASEM Cu Control		362	-200	1.708	0.758
		Delta	-30	12	0.02	0.038
		%Delta	-8.3%	-6.0%	1.2%	5.0%

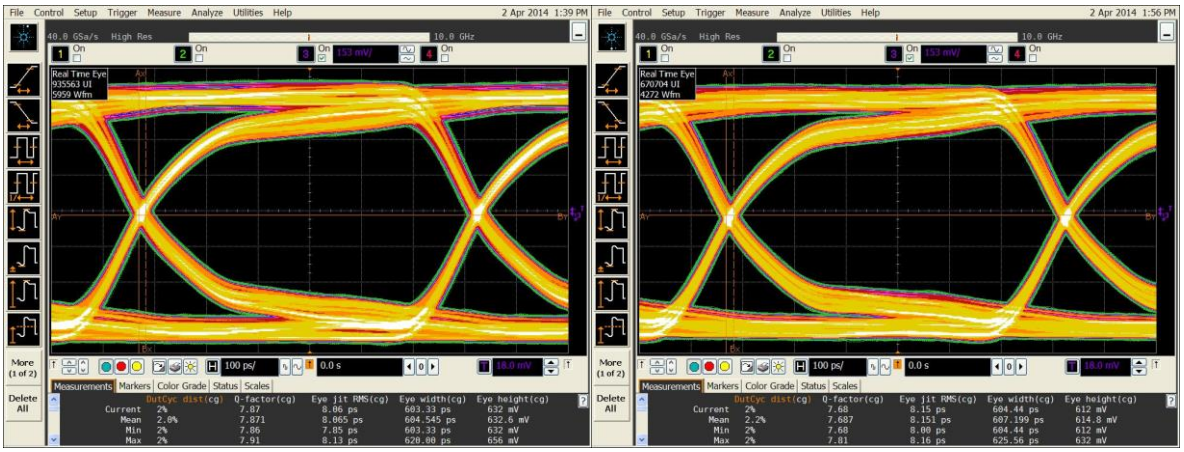
As expected, SSO measurements of output high and low disturbs vary by less than 10%. This is within experimental variation.

SERDES PERFORMANCE

Similar to SSO performance, increased inductance due to bond wire geometry could affect high-speed operation. The LFE3-150EA was chosen as a characterization vehicle so that SERDES performance could be quantified.

Three units of LFE3-150EA were programmed with an actual customer pattern that internally generates a PN7 pattern that is then transmitted over the SERDES channel. Eye diagrams and jitter measurements were collected at nominal temperature and voltage to compare relative performance. Pre-emphasis is off.

LFE3-150EA 1156fpBGA Eye Diagrams (3.07Gbps)



AMKOR ASEM (Control)

	Duty Cycle Dist (%)	Eye Jitter (ps)	Eye Width (ps)	Eye Height (mV)
Amkor	2.00	8.07	603.35	624.95
ASEM (Control)	2.10	8.02	605.37	634.25
Delta	-0.10	0.06	-2.02	-9.30
% Delta	-4.8%	0.7%	-0.3%	-1.5%

SERDES Jitter Statistics

As can be seen by the eye diagrams above, SERDES performance has not been measurably affected by the BOM change.

SUMMARY

There are no significant electrical performance issues related to the new alternate qualified material from AMKOR. Lattice recommends the production release of products from Amkor Philippines.