May 14, 2012

Subject: Characterization Summary – Copper Bond Wire at ASEM

SUMMARY

Per PCN# 09A-12, Lattice is now offering alternate qualified material sets that utilize Copper bond wire (Cu-wire). This document will summarize the electrical characterization that supports that conversion.

The scope of this document covers products manufactured at ASE Malaysia (ASEM).

METHODOLOGY

The characterization plan focused on three items:

1) Assembly Yield and Electrical Test Yield
2) Assessment of Critical Parameters
3) SSO (Simultaneous Switching Output) Characteristics
4) SERDES performance (LFE3-150EA only)

Product/Package combinations 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	Au-Wire (Control)			Cu-Wire (New)		
	Mold Compound	Wire/ Diameter	Die Attach	Mold Compound	Wire/ Diameter	Die Attach
LFE3-150EA/ 1156-fpBGA	Hitachi CEL9750HF10ALKU	0.9mil 2N Au	Ablebond 2100A	Sumitomo EME G750SE	0.8mil Pd Coated Cu	Ablebond 2100A
LFXP2-17E/ 256-ftBGA	Hitachi CEL9750HF	0.9mil 2N Au	Ablebond 2100A	Sumitomo EME G750E	0.8mil Pd Coated Cu	Ablebond 2100A
LFXP2-5E/ 144-TQFP	Hitachi CEL9510HF10-U	0.9mil 2N Au	Ablebond 3230	Sumitomo EME G700Y	0.8mil Cu	Yizbond 8143

Multiple lots of various product/package combinations were built as part of the qualification process for the new Cu-wire BOM. Samples from the qual lots were characterized and compared to comparable lots processed with the existing Au-wire BOM.

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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 Au-wire BOM.

	Assembly Yield		Electrical Yield	
	Au-wire (Control)	**Cu-wire**	**Au-wire (Control)**	**Cu-wire**
Copper Lot 1 Qty= 203	1.0	1.06	1.0	1.03
Copper Lot 2 Qty= 214		1.05		1.00

LFE3-150EA 1156-fpBGA Yield Summary

	Assembly Yield		Electrical Yield	
	Au-wire (Control)	**Cu-wire**	**Au-wire (Control)**	**Cu-wire**
Copper Lot 1 Qty=414	1.0	0.99	1.0	0.99
Copper Lot 2 Qty= 867		1.01		1.00

LFXP2-17E 256-ftBGA Yield Summary

	Assembly Yield		Electrical Yield	
	Au-wire (Control)	**Cu-wire**	**Au-wire (Control)**	**Cu-wire**
Copper Lot 1 Qty = 1682	1.0	0.99	1.0	1.00

LFXP2-5E 144-TQFP Yield Summary

There are no discernable differences in either assembly yield or electrical final test yields between the Cu-wire and Au-wire assembly processes.

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CRITICAL PARAMETERS

For the purposes of this characterization, critical parameters are defined as speed, power and I/O leakage. Samples of the Cu-wire qualification lots were tested at the same time as comparative Au-wire product. The tabulated statistics, Cpk values and histograms of the actual distributions are shown below.

All of the critical parameters are from the device datasheet except for Tpdcounter. Tpdcounter is a Built-in Self Test (BIST) routine that is correlated to datasheet parameters. Higher counts equate to faster devices.

Note that there is no significant change in the Cpk values between the various BOMs, which indicates that there is no significant parametric difference between Au-wire and Cu-wire. In most cases, the copper samples have better performance than the gold samples but the delta is small and not statistically significant.

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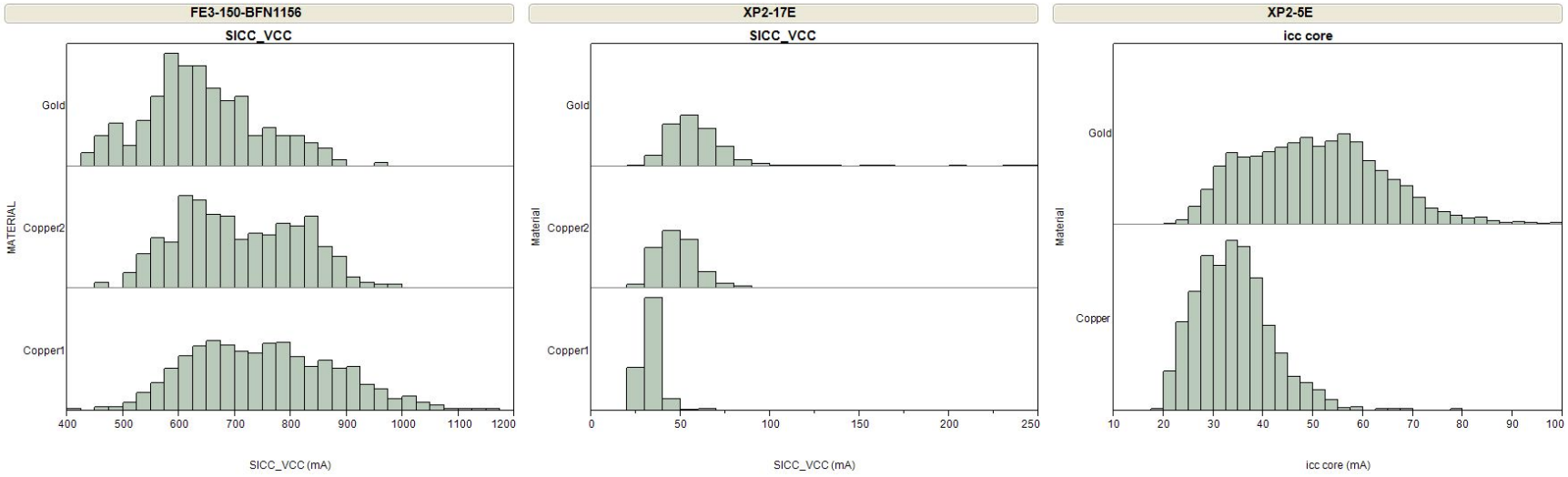
			Icc (mA)			
		N	Mean	Std	Spec (max)	Cpk
LFE3-150EA 1156 fpBGA	Copper Lot #1	980	752.40	125.91	2693	5.14
	Copper Lot #2	385	706.99	107.23	2693	6.17
	Gold (Control)	368	642.19	100.98	2693	6.77
LFXP2-17E 256 ftBGA	Copper Lot #1	393	33.35	5.24	395	23.01
	Copper Lot #2	394	47.97	10.36	395	11.17
	Gold (Control)	1298	58.22	16.40	395	6.85
LFXP2-5E 144 TQFP	Copper Lot #1	1595	34.13	7.44	172	6.18
	Gold (Control)	3117	50.06	13.08	172	3.11



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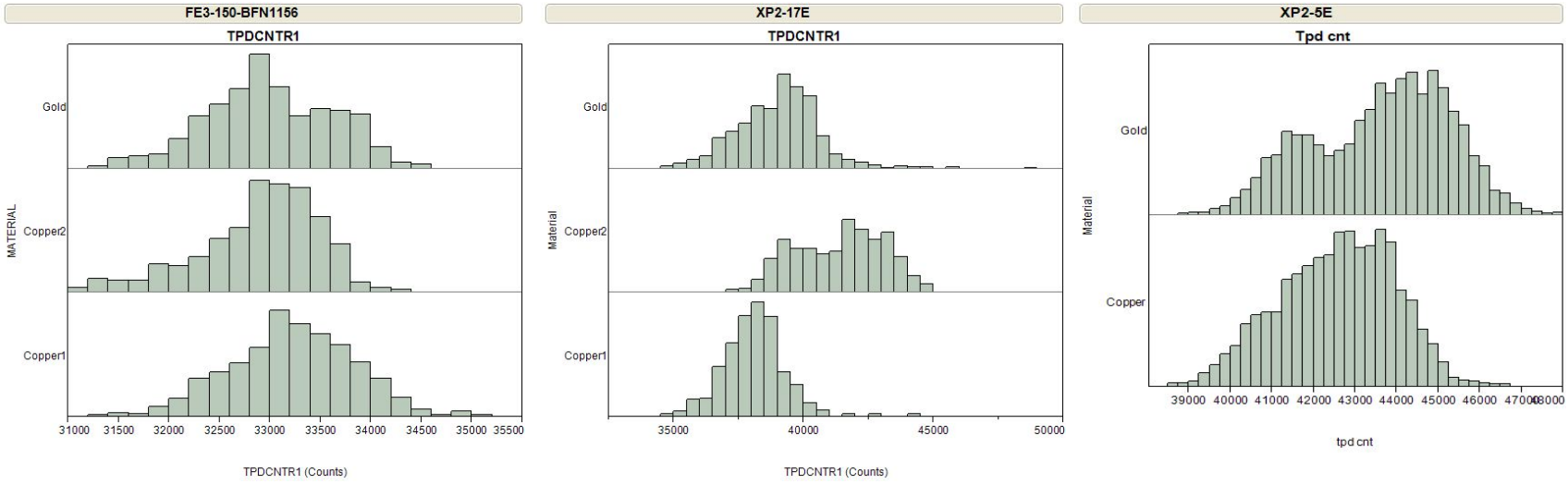
		Tpdcount (counts)				
		N	Mean	Std	Spec (min)	Cpk
LFE3-150EA 1156 fpBGA	Copper Lot #1	980	33228	597	26561	3.72
	Copper Lot #2	385	32904	594	26561	3.56
	Gold (Control)	368	33002	620	26561	3.46
LFXP2-17E 256 ftBGA	Copper Lot #1	393	38094	1137	32000	1.79
	Copper Lot #2	394	41418	1676	32000	1.87
	Gold (Control)	1298	39024	1508	32000	1.55
LFXP2-5E 144 TQFP	Copper Lot #1	1595	42582	1363	32000	2.59
	Gold (Control)	3117	43642	1636	32000	2.37



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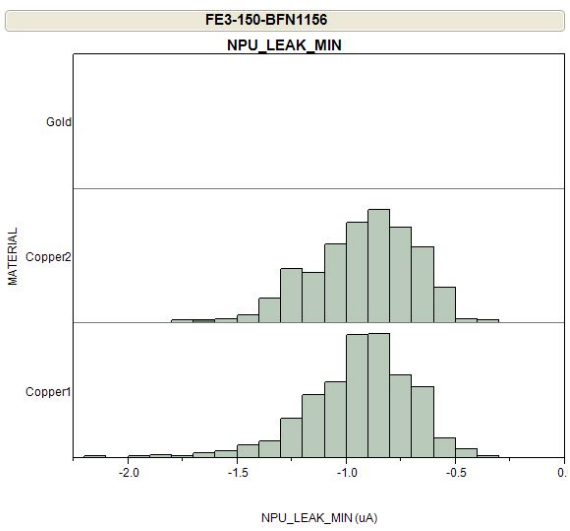
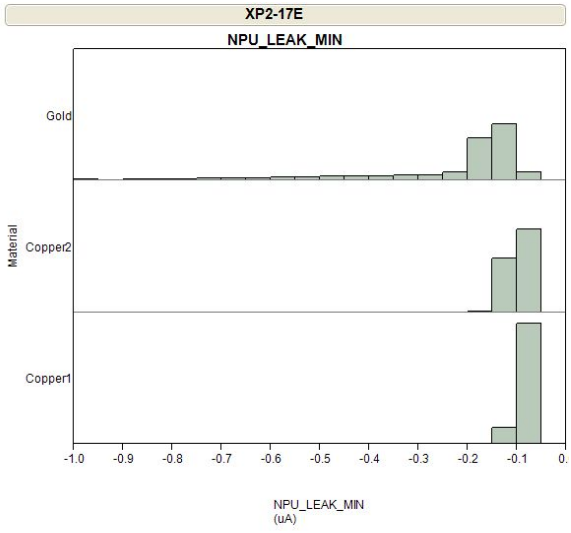
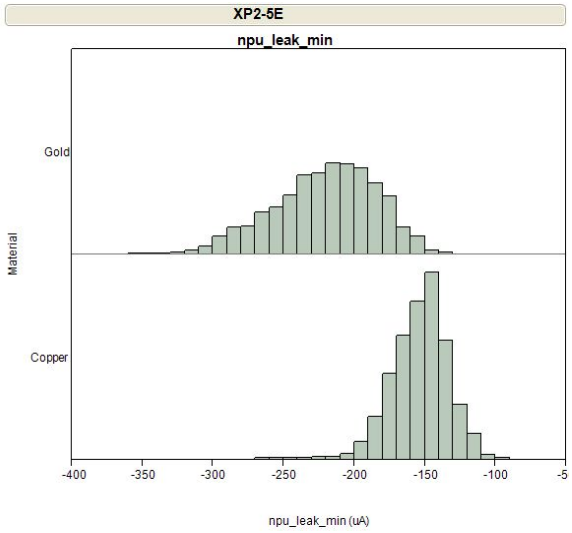
			IO Leakage (uA)			
		N	Mean	Std	Spec (max)	Cpk
LFE3-150EA 1156 fpBGA	Copper Lot #1	980	-0.94	0.24	10	15.19
	Copper Lot #2	385	-0.92	0.23	10	15.83
LFXP2-17E 256 ftBGA	Copper Lot #1	393	-0.09	0.01	10	336.33
	Copper Lot #2	394	-0.1	0.01	10	336.67
	Gold (Control)	1298	-0.2	0.13	10	26.15
LFXP2-5E 144 TQFP	Copper Lot #1	1595	-0.15	0.02	10	169.17
	Gold (Control)	3117	-0.22	0.04	10	85.17







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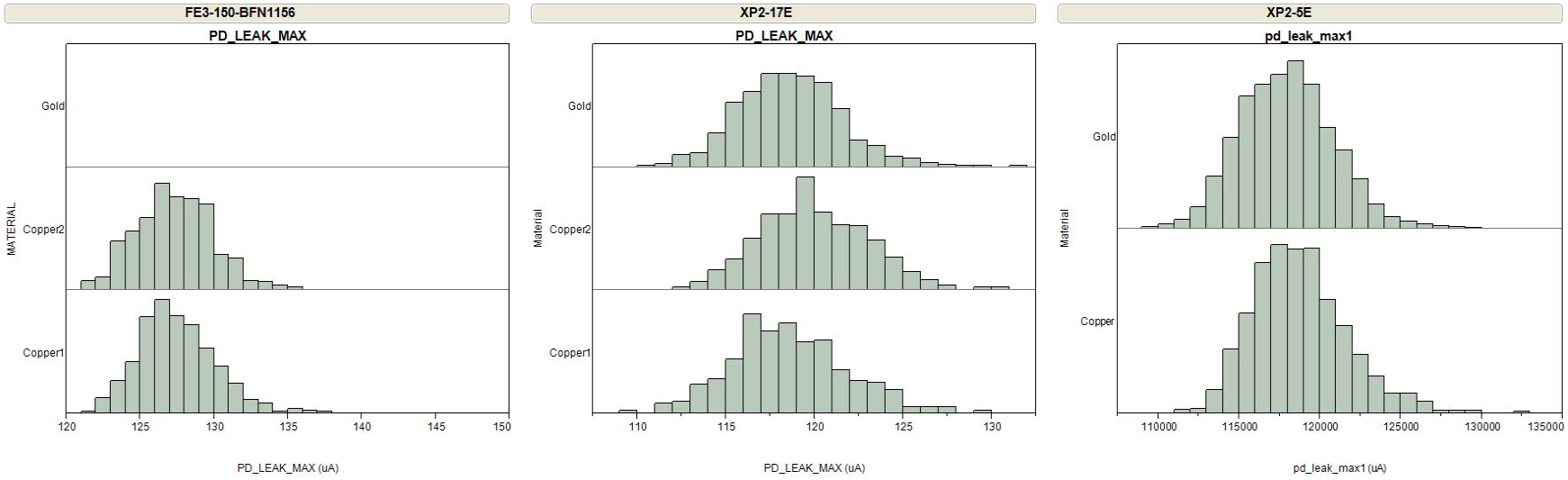
			PullDown Leakage (uA)			
		N	Mean	Std	Spec (max)	Cpk
LFE3-150EA 1156 fpBGA	Copper Lot #1	980	127.48	2.54	210	10.83
	Copper Lot #2	385	127.31	2.50	210	11.03
LFXP2-17E 256 ftBGA	Copper Lot #1	393	118.53	3.19	210	9.56
	Copper Lot #2	394	119.94	2.98	210	10.07
	Gold (Control)	1298	118.61	2.85	210	10.69
LFXP2-5E 144 TQFP	Copper Lot #1	1595	121.01	2.92	210	10.16
	Gold (Control)	3117	120.28	2.88	210	10.38



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SIMULTANEOUS OUTPUT SWITCHING PERFORMANCE

Since the bond wire diameter is changing slightly as part of this BOM change, it is important to quantify the Simultaneous Switching Output (SSO) performance. This characteristic is also referred to as Ground Bounce, although it can affect both power and ground supply rails.

Reduced bond wire diameter has the effect of increasing the inductance of the bond wire, which can affect SSO performance. Note that bond wire inductance is not a strong function of the bond wire material (Au vs. Cu). The main factor is simply the bond wire geometry (length and diameter). The following measurements are averages of 5 units per package type. All data with respect to ground.

Device-Pkg	Vcc	# Output Switching	Bondwire Diameter(mil) Material	Ground Bounce		Supply Bounce	
				Overshoot	Undershoot	Overshoot	Undershoot
				mV	mV	V	V
LFE3-150EA 1156-fpBGA	1.2V	60	0.9Au	233.4	-89.1	1.33	1.01
		60	0.8Cu	230.9	-85.9	1.31	0.97
		Delta		-2.5	-3.2	-0.02	0.04
		% Delta		-1.10%	-3.59%	-1.68%	3.50%
LFXP2-17E 256-ftBGA	1.2V	10	0.9Au	141.3	-29.0	0.67	0.42
		10	0.8Cu	129.4	-31.4	0.70	0.43
		Delta		-11.8	2.4	0.02	-0.01
		% Delta		-8.38%	8.29%	3.27%	-2.81%
LFXP2-5E 144-TQFP	1.2V	18	0.9Au	173.8	-80	0.95	0.41
		18	0.8Cu	174.4	-84.2	0.95	0.37
		Delta		0.6	4.2	-0.0052	0.04
		% Delta		0.37%	5.20%	-0.55%	9.03%

In the calculations above, a positive delta indicates that the Cu-wire BOM has more under or overshoot than the control Au-wire BOM.

The biggest absolute change from Au-wire to Cu-wire was on the LFXP2-17E. That part had 8.38% less ground bounce with Cu-wire as compared to Au-wire. The Ground undershoot was

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also 8.29% greater for Cu-wire than for Au-wire but this is the benign case where ground is going more negative.

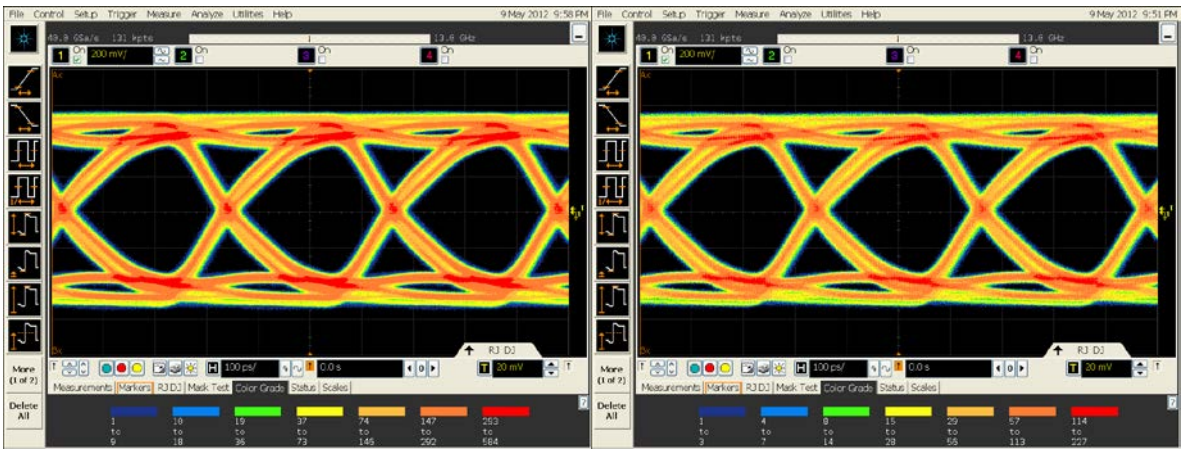
The largest adverse increase in SSO for the Cu-wire BOM was the supply undershoot of the LFXP2-5E which was 9% worse than Au-wire. This is within the calculated design tolerance of 10% and should not be an issue for a customer.

SERDES PERFORMANCE

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

Three units each of Au-wire and Cu-wire were programmed with a BIST pattern that generated a PN7 pattern that was then transmitted over the SERDES channel. The eye diagrams below are at 3.125Gbps and are nearly indistinguishable.

LFE3-150EA 1156fpBGA Eye diagrams (3.125Gbps)



Au-Wire Cu-Wire

Eye diagrams are a good qualitative measure of SERDES performance but a more quantitative approach is to compare parametric jitter measurements.

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The table below compares Cu-wire and Au-wire jitter measurements at various bit rates. In all but one case, the slightly increased bond wire inductance appears to improve jitter of the Cu-wire devices.

	Cu-wire Units (sample of 3)					
	3.125Gbps	**2.5Gbps**	**1.25Gbps**	**622Mbps**	**250Mbps**	**150Mbps**
Total Jitter (ps)	108.0	101.0	168.1	316.7	328.8	514.2
Random Jitter (ps)	4.9	5.0	10.9	20.5	22.9	32.6
Determinstic Jitter (ps)	36.1	30.2	12.1	31.7	33.5	50.7
	Au-wire Control Units (sample of 3)					
	3.125Gbps	**2.5Gbps**	**1.25Gbps**	**622Mbps**	**250Mbps**	**150Mbps**
Total Jitter (ps)	108.6	97.9	174.1	331.0	423.8	632.4
Random Jitter (ps)	5.4	5.1	11.8	20.9	29.6	37.4
Determinstic Jitter (ps)	36.9	33.6	13.4	32.8	39.3	99.9
	Percentage Change (Red means Au was better than Cu)					
Total Jitter (ps)	1%	-3%	3%	4%	22%	19%
Random Jitter (ps)	9%	2%	8%	2%	23%	13%
Determinstic Jitter (ps)	2%	10%	9%	3%	15%	49%

LFE3-150EA Jitter Measurements

SUMMARY

There are no significant electrical performance issues due to the conversion from Au-bond wire to Cu-bond wire. Lattice recommends immediate conversion to the Cu-wire material set.

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REVISION HISTORY

Date	Revision	Section	Change Summary
May 2012	1.0	---	Initial document release covering PCN 09A-12

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