

NOVEL LEADFRAME-BASED PACKAGE PROVIDES PERFORMANCE BOOST FOR HARD DISK DRIVE DATA TRANSFER PERFORMANCE

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ABSTRACT

Increased storage densities and faster data transfer rates in Hard Disk Drive (HDD) applications require improved electrical and thermal characteristics within associated semiconductor packaging. A case study of a new IC packaging technology termed “FusionQuad” is presented. Effectively, FusionQuad represents the integration of QFN and TQFP technologies, providing exceptional electrical and thermal performance in a cost-effective leadframe-based package. FusionQuad also doubles external inputs and outputs (I/O) for a given leadframe package body size by eliminating the historical barrier of only peripheral leads.

Electrical and thermal performance comparisons with an exposed pad TQFP (ETQFP) for HDD applications are presented. Board level mounting and reliability results are also reviewed.

INTRODUCTION

Continued device integration and miniaturization, coupled with increasing system level electrical and thermal requirements, are pervasive across the semiconductor industry. Within a HDD application space, requirements push the limits of traditional leadframe based packaging technologies. While exposed pad leadframe packages provide an excellent thermal solution at a low cost, the peripheral-only lead configurations limit package I/O. Additionally, long electrical paths are typical from the device to the printed circuit board (PCB), which results in signal integrity concerns as frequencies increase.

FusionQuad is a novel integration of exposed leads on the bottom surface of a TQFP style package. The additional leads allow for approximately 50% reduction in package size for a given leadcount. For example, a 176 lead package, which is 20x20mm in a standard TQFP at 0.4mm lead pitch, is reduced to a 14x14mm FusionQuad with a larger 0.5mm lead pitch and achieves just over 50% reduction in footprint. Additionally, FusionQuad was designed to the VQFP thickness of 0.8mm resulting in a 0.2mm height reduction as compared to 1.0mm thick TQFP. The cost-effective miniaturization achieved with

FusionQuad is ideal for many applications within space and cost constrained electronic appliances.

The basic outline of FusionQuad is shown in Figure 1 combining standard 0.5mm pitch peripheral leads with two rows of inner lands at either 0.65mm or 0.5mm pitch. A dual row of inner lands is depicted, however, a single row of inner lands is also available. While 0.5mm lead pitch is generally preferred, 0.4mm pitch is also possible for both peripheral leads and inner lands. Combinational lead pitches are also feasible where the peripheral leads and inner lands are at different dimensions.

Figure 1. Top and bottom views of 14mm 176 lead FusionQuad



PACKAGE CONSTRUCTION

Package Structure

FusionQuad is based upon the same construction technologies as the TQFP. Construction begins with a copper-based leadframe which is produced by either etching or stamping and includes silver spot or NiPdAu overall

plating. Either plating type provides a wire-bondable surface, while NiPdAu also provides solderable external I/O and eliminates the need for subsequent leadfinish plating during the assembly process. Cross-sectional views, which compare standard TQFP to FusionQuad, are shown in figures 2 and 3.

Figure 2. Side view of TQFP (1.0mm thick)



Figure 3. Side view of FusionQuad (0.8mm thick)



Process Flow

FusionQuad derives its low cost manufacturing process from the current TQFP process. Conventional die attach is used to mount the device or devices to the exposed pad die flag. Standard wirebonding processes are employed, however, special clamping is required for FusionQuad, due to the multi-level leadframe design. Standard automolding is used followed by deflash to completely expose bottom side lands. Device marking is followed by solder plating if the leadframe does not include NiPdAu. Conventional trimming is followed by form, singulate and final packing in the case of the single row configuration resulting in no additional process steps as compared to standard TQFP. For dual row inner lands, a saw isolation process is required following the trim process. The saw isolation process is based upon the well-proven saw QFN processes in production today. A comparison of the dual vs. single row process flow is presented in Figure 4.

Figure 4. FusionQuad Process Flows

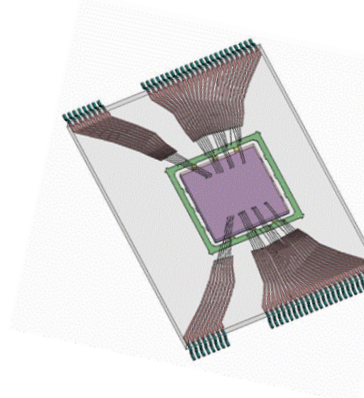
Dual Row	Single Row
Wafer Mount	Wafer Mount
Saw & Clean	Saw & Clean
Die Attach & Cure	Die Attach & Cure
Wire Bond	Wire Bond
IVI	IVI
Mold	Mold
Deflash	Deflash
Post Mold Cure	Post Mold Cure
Laser Mark	Laser Mark
Solder Plate	Solder Plate
Trim	Trim
Isolation Saw	Form Singulate
Form Singulate	Final Visual Gate
Final Visual Gate	Packing
Packing	

ELECTRICAL PERFORMANCE

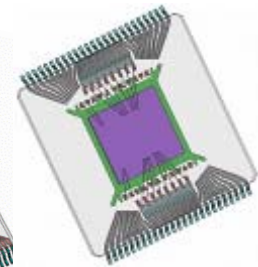
As serial data transfer rates continue to increase within the HDD application space, the electrical characteristics of the TQFP begin to limit performance. FusionQuad supplies inner lands very close to the read/write system on chip device (SoC), which provide excellent radio frequency (RF) characteristics to support high data transfer rates.

An electrical RF simulation was completed using Ansoft HFSS comparing the TQFP to the FusionQuad. Precise dimensions of all structural elements including wire-bonding loops were used to create the models. Figure 5 and Figure 6 show schematic views of the modeling environment.

**Figure 5
20mm epad TOFP**

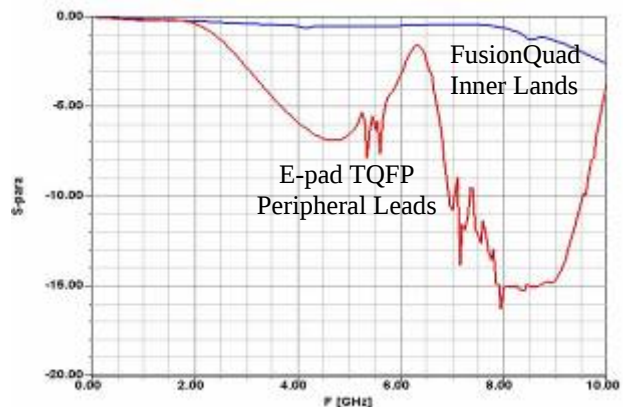


**Figure 6
14mm
FusionQuad**



In comparison of the results, FusionQuad offers a dramatic improvement in RF performance as frequency levels increase showing less than a 2 dB insertion loss across the entire RF range up to approximately 10 GHz. Standard TQFP devices showed significant degradation starting around 3 GHz. Figure 7 shows the electrical results.

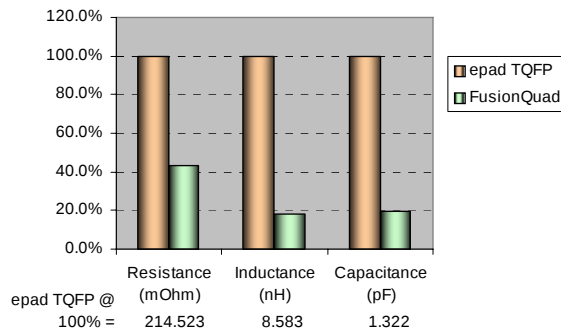
**Figure 7
Insertion Loss for Differential Pair**



During electrical simulation, signal net performance was analyzed comparing TQFP peripheral leads with FusionQuad inner lands. Dramatic reductions in self-

resistance (R), inductance (L) and capacitance (C) were observed as shown in Figure 8.

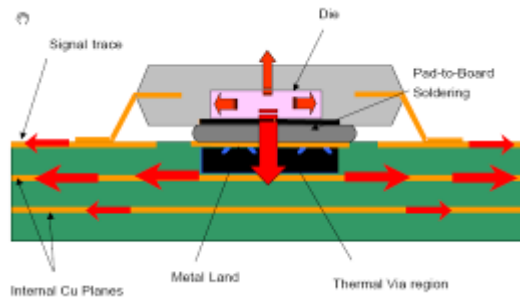
Figure 8. Comparison of RLC for TQFP vs. FusionQuad



THERMAL PERFORMANCE

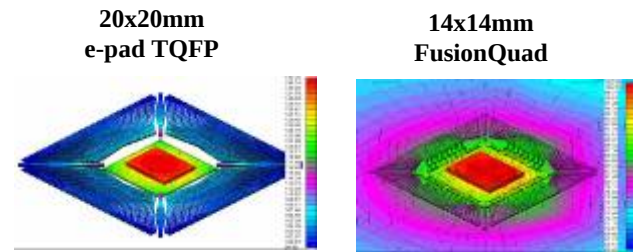
A variety of options exist to enhance thermal performance of IC packages to be capable of meeting the performance requirement¹⁻². In comparison of different leadframe and laminate options, the epad TQFP is capable of the best thermal performance at a low cost. As shown in Figure 9, the die flag is exposed and soldered to the system PCB during board assembly, which allows for a low resistance thermal path.

Figure 9. System Level Heat Transfer Schematic for epad TQFP



FusionQuad maintains approximately the same exposed die flag and low resistance path to the system PCB. However, it has additional advantages as compared to epad TQFP. Due to close proximity of lead tips to the device heat source as shown in Figure 3, leads now become active in the thermal equation, as shown in Figure 10.

Figure 10. Isotherms for epad TQFP vs. FusionQuad



As FusionQuad is only 0.8mm thick, practically the entire area of the package contributes to thermal dissipation as the leads now assist in carrying heat away from the device. The effective thermal dissipation area is increased for heat transfer; both down to the PCB, as well as up through the top surface of the package. As a result, FusionQuad offers approximately the same excellent thermal performance as a TQFP package in a footprint, which is fifty percent smaller. Comparative thermal characterization at the system level is ongoing and will be presented at a later date.

SOLDER PROCESS DEVELOPMENT

Board level mounting studies have been completed within Amkor, Seagate and a third party EMS provider. In all three factories, FusionQuad showed excellent process capability for a variety of board designs as well as stencil patterns and thicknesses. During evaluations, stencil thickness ranged from 100 to 125 microns with FusionQuad package standoff ranging from 50 to 100 microns nominal. Various solder paste-printing patterns, which ranged from 50 to 90% coverage of the exposed pad, were also examined. Every condition tested in all three factories resulted in 100% board assembly yield demonstrating the wide process window available for mounting FusionQuad. Figures 11 and 12 represent process success.

Figure 11. Photo of Mounted FusionQuad with Corresponding X-Ray Image Showing Excellent Wetting

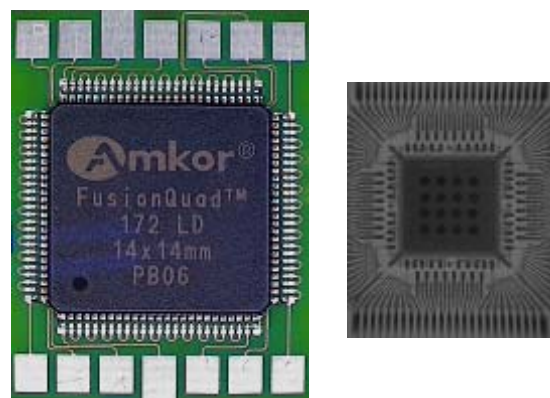
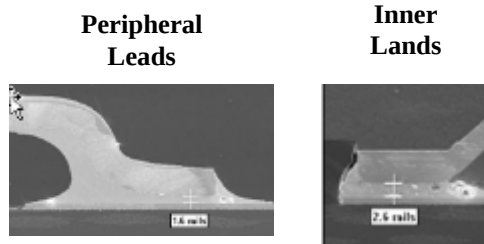


Figure 12. Representative Images of FusionQuad Solder Joints



Preliminary board level reliability tests showed excellent performance with FusionQuad. Electrical resistance was measured on each pin of serialized units after initial board mounting and after stress testing. Table 1 shows the results on a sample size of 24 mounted devices for each test condition.

Table 1. Board Level Reliability of FusionQuad Daisy Chain Devices

	1st Readout	2nd Readout
Temp Cycle	Passed	Passed
-55 to +125 C	100 cycles	300 cycles
Thermal Shock	Passed	Passed
-55 to +125 C	200 cycles	500 cycles
Biased Temp & Humidity 85/85	Passed	Pending
168 hours		
HTOL	Passed	Passed
125 deg C	168 hours	500 hours

A separate paper with more detailed board level mounting information and reliability results will be forthcoming.

CONCLUSION

Package construction, electrical and thermal performance as well as board mounting results of the new FusionQuad package are presented with reference to an epad TQFP baseline. Major conclusions include:

1. FusionQuad offers excellent RF electrical capabilities for increased data transfer rates within HDD applications.
2. Compared to an epad TQFP, FusionQuad offers approximately identical thermal performance for a given leadcount in a package body half the size.
3. FusionQuad offers significant miniaturization as compared to standard leadframe packages, which include only peripheral leads.

4. Conventional materials and leadframe based assembly processes are utilized in FusionQuad resulting in a cost effective manufacturing process and finished product.
5. FusionQuad offers a breakthrough in IC package performance providing excellent RF and thermal capabilities in a low cost miniaturized leadframe based package.

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