HDQFP packing in Tape & Reel and Tray:

Technical Challenges, Improvements and Results

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Quality of NXP's products is the company's highest priority. After packaging and testing to guarantee electrical parametric performance, parts must be delivered to arrive at the customer in impeccable condition.

HDQFP is a brand new development by NXP Tianjin, qualified in 2022, which adds ~70% more pins to a standard QFP. These leads are delicate and require precise and careful handling to avoid deformation. The physical packing materials used are key contributors to the quality of the deliveries.

Two types of deliveries are offered: Tape & Reel and Tray. Both of these carriers demanded fundamentally new designs to avoid bent leads. The designs were developed with iterative improvements using Six Sigma methods to analyze and correct weaknesses.

This paper introduces Tape & Reel, trays and HDQFP and explains the iterations made to successfully complete the project qualifications without schedule impact.

Keywords

HDQFP; Tape & Reel, Tray, Drop Test, Visual Mechanical Inspection, ATE, Burn-In

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Introduction

Trays

Trays have been used for handling of ICs since packages moved away from dual-inline to denser designs such as Quad Flat Pack, where legs are placed on all four sides of the package perimeter, or even more compact designs such as Ball Grid Array, where one complete surface of the package is dedicated to contacts.

Trays are used for all pick and place handling of ICs. They are usually molded from plastics or carbon fiber materials which are electrically conductive or dissipative in order to protect electrostatic-sensitive devices.

Trays are used throughout NXP's final manufacturing to carry packaged ICs from one machine to another, or during loading and unloading of test and stress equipment, e.g., automatic test equipment (ATE) testers or burn-in ovens. They have standardized external dimensions (X, Y, Z) and are laid out with rows and columns of cavities which are designed to carry a single IC of a particular package. Trays are stackable, so that by the inclusion of one empty tray at the top, every IC nestles in its own protected cavity with limited X, Y, Z movement.

By tightly wrapping the stacks of trays and placing them in precisely sized cardboard boxes, ICs can be delivered to customers. They can then unpack the ICs and use pick and place machines to populate their Printed Circuit Boards (PCBs). ICs will be typically soldered by reflow to these PCBs.

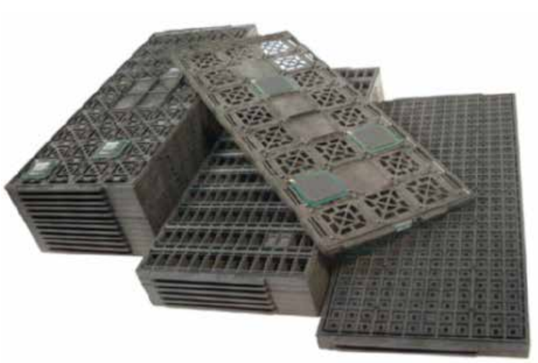


Figure 1: (c/o ePAK, Inc.) Trays Used for IC Handling

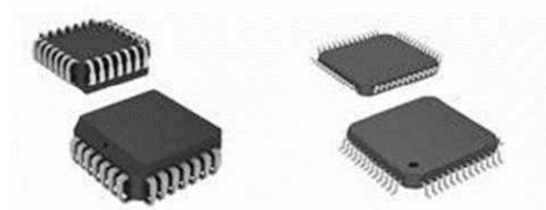
Tape & Reel

Tape and Reel was promoted in the 1990s by Japanese manufacturers to improve automation of the steps for IC unpacking and subsequent mounting. Machines are used by NXP to pick ICs from trays and place them in the pockets of a specific carrier tape, which are then closed with a thin plastic seal tape. The sealed tapes are wound onto reels before packing in boxes for final delivery.

Figure 2: (c/o ePAK, Inc.) Tape & Reel for IC Transportation

HDQFP

Two types of leaded packages succeeded dual inline designs to obtain higher density; Plastic leaded chip carrier and Quad Flat Pack. In particular, QFP became a popular industry standard as it allows medium-density packaging while offering good solderability and optical inspection, highly valued in automotive applications.

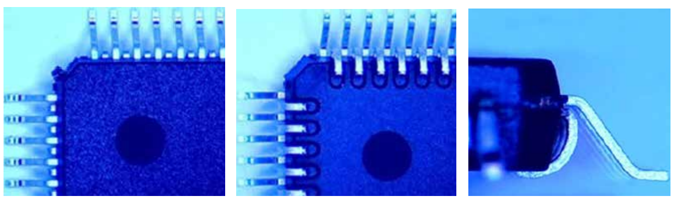


28-, 44-, 68-, 84-pin PLCC **32-, 44, 80-, 100-pin QFP**

Figure 3: Plastic Leaded Chip Carrier and Quad Flat Pack

Size and weight of packages are important factors which catalyzed iterative decreases of package height and lead pitch (from 0.8 mm to 0.65 mm, 0.5 mm and 0.4 mm.) 0.4 mm size is not popular due to the solderability concerns with the close proximity of the legs to their neighbors.

HDQFP is a completely new NXP Tianjin innovation which merges the lead shapes of PLCC and the QFP. It uses generous pitch dimensions of 0.65 mm which simplifies solderability. Standard visual inspection tools can be used by adjusting camera angles to monitor both the gullwing (QFP) and J-lead (PLCC) legs, which will allow HDQFP to become a popular and successful package.



Top View **Bottom View** **Side View**

Figure 4: HDQFP Images

The mechanical criteria for the legs are determined by these parameters:

Standof = absolute distance of leg to body

Coplanarity = relative displacement per leg

Bent leg = lateral displacement of each leg

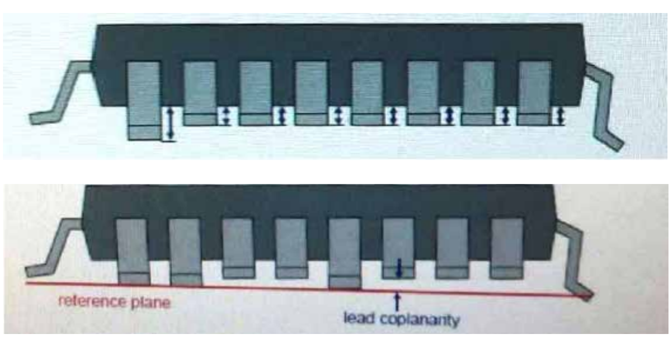


Figure 5: Standoff and Coplanarity

Drop Test

Drop tests can be conducted manually but are best executed with a specific machine:

Figure 6: Drop Test Machine

- 10 drops from 1.0 m:
  - 6 faces
  - 1 corner
  - 3 edges

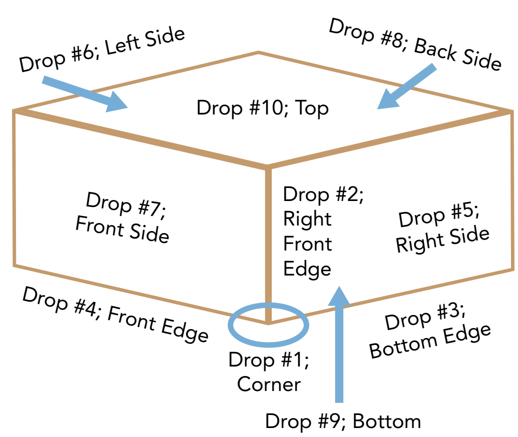


Figure 7: Drop Test Angles

The criteria to pass the Drop Test after 10 Drops are Zero- Failure of all Visual Mechanical checks on every leg on every device with respect to Standoff, Coplanarity and Bent Legs.

Tray and TAPE & REEL Initial Design

The original Tray and Tape & Reel designs relied upon fences between the J-leads and the gullwing leads, as well as stops beneath and above the package body. The target (standard) quantities are five trays of products or 500 parts per reel.

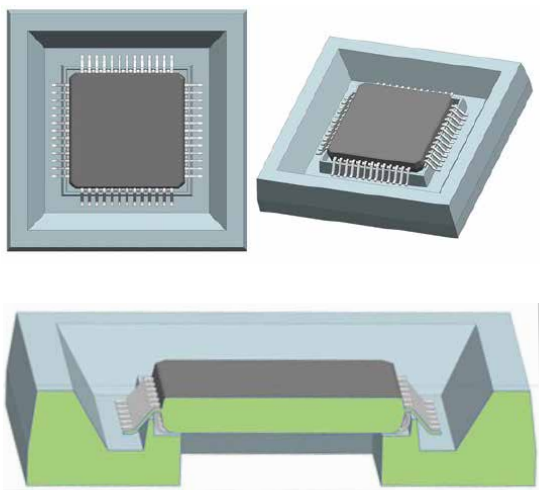


Figure 8: Tape Pockets with HDQFP in Cavity

The trays and reels were submitted to drop tests with maximum quantities. See the following diagrams.

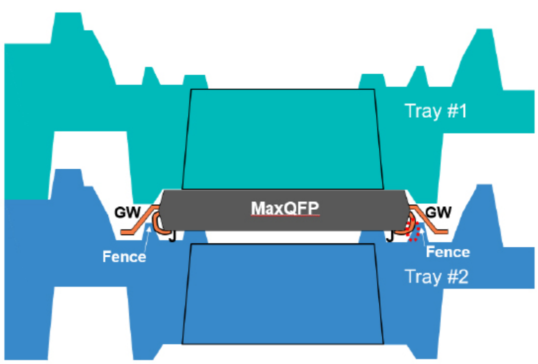


Figure 9: Stacked Trays with HDQFP in Cavity

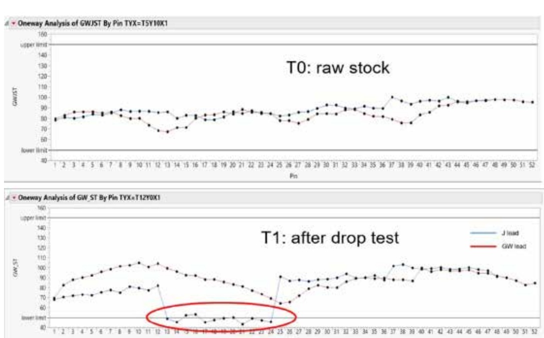


Figure 10: Stacked Trays with HDQFP in Cavity

The drop test failed the coplanarity check on 7% of the devices with damage to the J-leads.

Root-cause analysis concluded that lateral movement of the HDQFP in its cavity could lead to damaging collisions with the fence, See Figure 11:

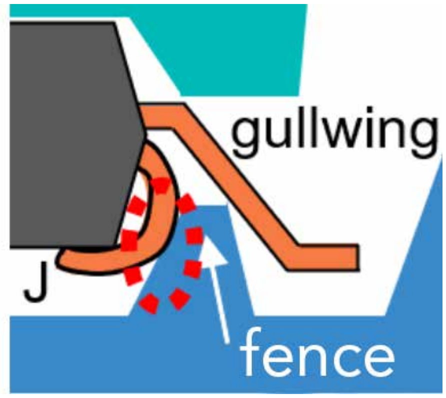


Figure 11: Drop Test Caused J-Lead to Hit Fence

A second version of the tray with a smaller pocket design to reduce movement also caused bad results with 5 stacked trays:

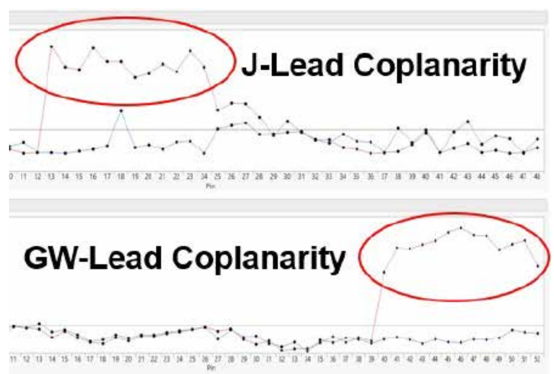


Figure 12: Drop Test with Version 2 Damaged GW and J-leads

A third version of the tray with a larger pocket design to allow lateral movement caused even worse results with five stacked trays after drop tests.

As an interim containment action, successful drop test results with only three trays of Version 2 allowed delivery of early customer engineering samples. Tape & Reel delivery was possible but with only 100 parts per reel.

Tray and TAPE & REEL new concept

It was concluded that radical changes were needed to the basic design. Placing fences between the gullwing and J-leads was clearly not going to lead to successful drop-test results. A completely new concept for tray and Tape & Reel cavities was developed using corner posts or corner fence. The corner posts only touched the plastic compound in each corner of the HDQFP. Lateral movement in X and Y direction was not completely prevented, but in every case, the body of the package hit the corner post and no contact was made between the leads and the tray or tape:

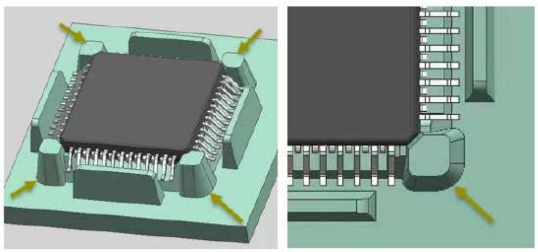


Figure 13: Revised Design Concept for Tray with Corner Posts (Without Fence)

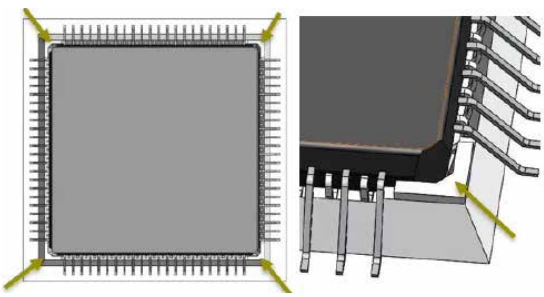


Figure 14: New Design Concept: Tape & Reel Corner Guides (Without Fence)

The revised tray and tape versions with corner posts and corner guides but with removed fences successfully passed drop tests for 172HDQFP and 100HDQFP with five stacked trays and 500 parts per reel respectively.

Conclusions

Applying Six Sigma analysis methods (DMAIC in particular) and forming a constructive collaboration between AP Product Engineering, ATTJ Manufacturing and a tray and Tape & Reel vendor allowed NXP to successfully engineer solutions for packing materials for the HDQFP new technology introduction.

Acknowledgements

Major contributions by X.S. Pang, Fiona Guo and David Yang, among many others at ATTJ.

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After graduating in Electronic Information Engineering from Tianjin University of Technology and working for four years in Antronix Electronic Company as an RF design engineer, Edward joined Foxconn Tianjin in 2009 as a Production Engineer. At Foxconn, he was responsible for the new product introduction and DFx work in server manufacturing. In 2015, he joined Continental Tianjin as a quality engineer and was responsible for process and customer quality. He joined NXP Semiconductors Tianjin in 2016 as an NPI Product Engineer and participated in the new product introduction of two generations (K1 and K3) of products, particularly the industry-first HDQFP package development.

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After graduating Summa Cum Laude in Computer Science from Edinburgh University and working for four years at a Swiss startup, Michael joined Philips Semiconductors Zurich in 1986 as a Test Engineer. In 1995, he moved to Motorola Munich to work on the first generation of automotive microcontrollers with embedded NVM and analog. As of 1998 he managed teams of test engineers and product engineers in Toulouse's Analog division. Since 2016, he has led the 32-bit Automotive Microcontrollers with Embedded NVM and Analog Team in Tianjin, China.

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Document Number: HDQFPPKGWP REV 1