ENHANCED MANUFACTURING SERVICES 4.0: THE DIGITAL SUITE TO SUPPORT INDUSTRY 4.0 FROM ELECTRONIC DESIGN TO DELIVERY ARTICLE 3 – DISCOVER GOLD IN YOUR PRODUCTION & TEST DATA

This final article in the trilogy describes ASTER's vision of the Design to Delivery flow, by applying Industry 4.0 principles. The article focuses on how traceability & test contributes to **understand the defect universe** and helps to improve the design of subsequent products.

NFF: NO FAULT FOUND

When looking at the quality data of products returned from the end-users, there is a key metric: No Fault Found (NFF). According to the Accenture Report, around 70% of all product returns were characterized as NFF. Cost-wise (including returns processing, scrap and liquidation), NFF amounted to 50% of a total 13.8 billion USD return and repair costs. This only covered the USA.

Through the BASTION research program, ASTER and a consortium of European universities and industrial partners have investigated the No Failure Found (NFF) phenomenon.

There is a different interpretation depending on the industry segment. The most popular definition is "A PASSED product which is FAILED at the customer site". Sometimes, the definition is reversed "A FAILED product at the customer site, which PASSES when returned to the production facility".

The NFF phenomenon is extremely hard to study, given a need to analyze faults which have not been detected. As they are not detected, there is no data to understand root causes or adequate actions. It is difficult, therefore to anticipate the defect occurrence and defect detection by using innovative test functions.

"How to know what is unknown?"

There is some sort of philosophical statement that says: "There are known knowns; there are things we know we know. We also know there are **known unknowns**; that is to say we know there are some things we do not know. But there are also unknown unknowns – the ones we don't know we don't know.".

The defects which are detected during board-level integration or system-level test should have only two sources:

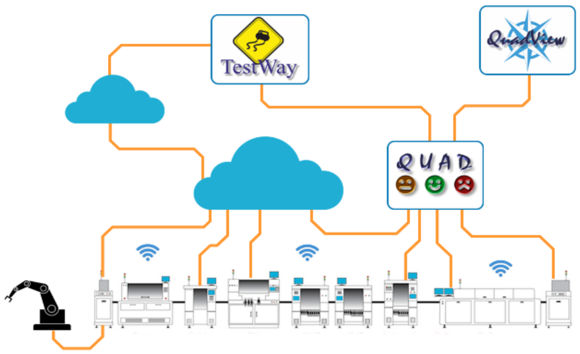
1. The defect occurs later, after board test (damage or aging) and/or the fault is intermittent.
2. The defect is already on the board prior to the integration level, but the board test is not able to detect the defect. This might be due to a lack of coverage (*Slip*), wrong coverage metrics or a defect universe, misaligned with the industrial reality.

TRACEABILITY & REPAIR TOOL

In the second article, Test coverage has been introduced as the key qualification tool for driving schematic design, board layout and test program development, as well as enabling the best production yield. A number of different test coverage models ranging from MPS to PCOLA/SOQ and PPVS have been developed, defining how the coverage metric is calculated using different defect models.

With the demonstration that Test Coverage and DPMO are strongly linked through the Production Model, knowledge of probable defects is as important as the knowledge of test coverage.

ASTER is developing QUAD (QUalityADvisor). This is a flexible and modular software tool, built around a centralized and open architecture database, for providing traceability of any PCBA production data. It helps to accurately retrieve data and convert it into meaningful information that can be used to fine tune the product life cycle.



QUAD system overview.

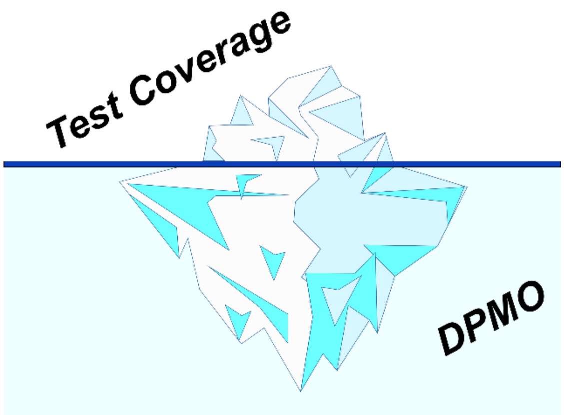
BIG DATA

A product is passed through a test line which, step by step, detects specific types of defects. The production information is stored in a centralized database for traceability purposes. With Industry 4.0, raw data from various machines are aggregated to build and visualize comprehensive information that allows humans to understand the defect universe.

Both DPM (Defect Per Million) and DPMO (Defect Per Million Opportunities) are used for determining the overall quality of the UUT (Unit Under Test), produced from the sample quantity inspected. DPM is a measure of manufacturing throughput: how many bad parts slip through the manufacturing process. DPMO is a measure of performance: how many times a manufacturing defect class occurs. DPMO is also an indicator of which manufacturing process is in need of improvement.

Test strategy and defect occurrences should be linked together so that improved test coverage can be targeted towards defects that occur frequently. A lack of coverage on defects that never occur has no real bearing on the final product quality.

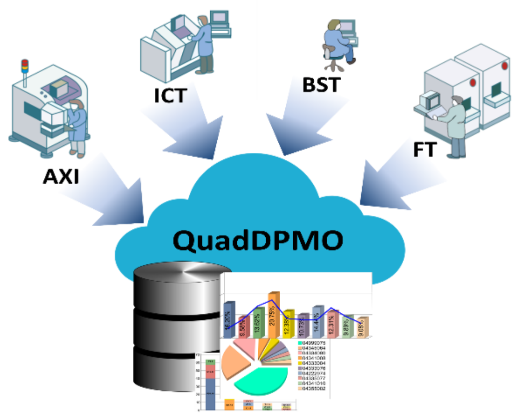
It is necessary to go beyond solving surface issues and qualify the product test strategies against the real DPMO.



QUADDPMO

ASTER expanded their Digital suite with an innovative software tool named QuadDPMO that:

- Aggregates the Traceability and Repair database.
- Enriches the manufacturing & test information with CAD data, and test coverage database.
- Groups defect labels and root causes, by defect class.
- Investigates common areas of occurrence for each defect class.
- Computes long term, medium term and short term DPMO metrics.



QuadDPMO Synopsis

QuadDPMO produces reports where test data can be analyzed by site, period of time, test station, batch ID and product ID. It gives access to detailed reports where the defect family, defect code or defect label, can be sorted by various attributes, such as: pin count, pitch, mounting technology, mounting side, JEDEC shape, manufacturer, component function, board complexity, board type…

The chart (pie or bar graph) color code can then be automatically transferred to the layout, or schematic views, in order to verify that the defect occurrence is linked with a physical or logical location (functional block).

As the QuadDPMO database includes CAD data, test coverage metrics, as well as test and repair information, it is possible to extract the real DPM per component population.

From processing the QuadDPMO database, a DPM table is produced which highlights the amount of PPM per defect category. The PPM information can then be imported by the TestWay test coverage tool and used to measure the deviation between the theoretical defect rates and the real defects that are extracted from the traceability and repair database.

There are two strategic benefits:

1. If the theoretical defect rate is higher than the real DPM, test coverage has been developed to detect defects that don't, or only rarely occur. This provides an opportunity to optimize the test strategy, by focusing on the most probable defects. This optimization could be static (done one time for the overall PCBA production), or dynamic (adjusted in real time by disabling some tests when the DPM is decreasing). The dynamic mode can facilitate an increased throughput, if the test becomes a bottleneck within the production line. Alternatively, specific test lines could be selected based on their capability to detect certain defects, thereby tuning the test line to the product being manufactured. This capability could be expanded to allow OEM companies to select an EMS company, based on their process capability as reflected by their DPM figures.
2. If the real DPM is higher than the theoretical defect rate, it means better test coverage is required on certain components, in order to prevent a higher escape rate, which, in turn, contributes to the No Fault Found (NFF) phenomenon.

An example of theoretical versus real DPM:

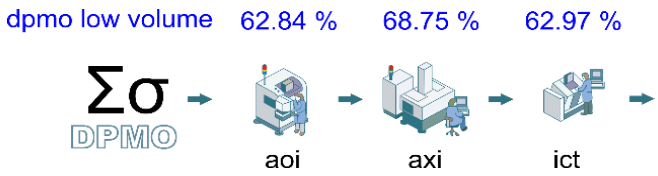


Figure: Test Coverage with standard DPM

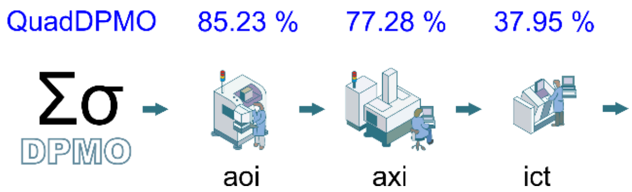


Figure: Test Coverage with real DPM

The AOI and AXI inspection strategies, target the defects that occur most often, which results in an increase in the weighted test coverage. Whereas an ICT test strategy targets defects with a lower level of occurrence, resulting in a reduced weighted test coverage. Defect distribution highlights that the "Presence", "Alignment", "Quality" and "Open" defects are targeted more by inspection techniques such as AOI and AXI, whereas the ICT test strategy is mainly targeting "Live" defects.

It is a common misconception that inspection alone is an acceptable test strategy. Some defects are addressed exclusively by electrical tests such as BST, FPT, or ICT. Only an electrical test can confirm solder conductivity and detect all possible instances of shorts and opens. Functional test is still relevant since it proves the product is fit for purpose.

CONCLUSIONS

The first article in this trilogy examined ASTER's new vision of an Enhanced Manufacturing Services 4.0 workflow that applied the principles of Industry 4.0 to improve decision making, create a faster time-to-market and produce products more cheaply with better quality.

The second article focused on the concept of New Product Introduction driven by test coverage. The purpose of any test solution is to maximize test coverage to ensure that the majority of defects are detected, while minimizing the test cost.

This final article highlights that the improvement of product yields does not simply mean better product quality at a lower cost, but also acquiring a deeper understanding of the whole manufacturing process by making full use of manufacturing information. This can lead to improved product reliability, prevention of re-occurring defects, improved future product designs and increased competitiveness.

Using Digital Simulation, TestWay creates a virtual copy of the physical world. It allows "What-if" scenarios played in the virtual word to identify the optimal physical flow, using theoretical results to control the physical world.

The EMS 4.0 workflow enables tremendous benefits in time-to-market, cost reduction and quality improvements.

Realize your digital transformation now with the ASTER digital suite including TestWay, QUAD and QuadDPMO.

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