Printed Board Assemblies Test Coverage Calculation: New Calculation Method

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Abstract *— There are three ways that major industries use to calculate Printed Board Assemblies Manufacturing Test Coverage. The problem with these methods is that they combine parameters that are either relative to inspection or testing to provide an overall Test Coverage. This may lead to misinformation and making wrong decisions such as removing inspection or test steps due to complacency with Test Coverage results. A survey was performed to understand better which method is being used and the needs the users have. To generate a new method of calculating the Printed Assemblies Board Manufacturing Test Coverage, the results were analyzed, requirements were established, and a new method was designed. A way to test this method needs to be generated using the Printed Board Assembly Complexity Index.*

Key Terms *— Electrical Testing, Inspection, Printed Board Assemblies, Test Coverage.*

INTRODUCTION

When calculating Printed Board Assemblies Test Coverage, often Test Engineers encounter issues when explaining overall test coverage to other Engineers or Management that are not often involved in manufacturing or test processes. The three major formulas to calculate PBA Test Coverage Assemblies combine parameters that are either related to testing or inspection. The researcher wanted to develop a new way to calculate PBA Test Coverage that would avoid misunderstandings and the removal of necessary steps during PBA Manufacturing. The research looks to provide a new way of calculating Printed Board Assemblies Manufacturing Test Coverage that can differentiate between Inspection and Testing. Moreover, while differentiating it, the proposed alternative will help improving the quality of tests and inspection performed on products thus improving the quality of the product delivered to customers. The results of this research will also contribute to a field that is currently dominated by companies providing test and inspection services.

LITERATURE REVIEW

Every Printed Board Assembly manufacturer test and inspect the products before shipping them to customers. At what level these should be inspected or tested? When asked, many engineers will say that the goal of a Test Plan for a PCB is 100% test coverage. When pressed further, they usually admit that 100% test coverage is virtually impossible to achieve [1]. Calculating the Printed Board Assembly Test Coverage requires understanding of the PBA complexity, manufacturing test processes, possible defects and test methodologies.

Optimum Test Coverage

Not all components can be tested on a Printed Board Assembly. “Cost is at the top of the list of restraining factors” [1]. Other factors such as higher density boards also restrain the possibilities of a 100% of test coverage [2]. Optimization and a possible high score need to be determined to keep a balance between improving manufacturing yields, product quality and marketplace competitiveness [1].

PCB Complexity

“The PCB Complexity directly impacts the number of possible defects it has, which also affects the test strategy selection” [2]. Across industry DPMO or Defects Per Million Opportunities is used to calculate Yield. A complex Index was introduced to separate PBA complexity on 3 different categories: Low Complexity, Medium Complexity and High Complexity. This complexity is measured

and divided according to the quantity of DPMO's per board.

Manufacturing Test Processes and Defects

Different Test Methods can be tailored depending on the manufacturing processes to optimize the capture of possible defects. Automated Optical Inspection can be used post pickle and place and during pre or post flow. Automated X-ray Inspection pre or post wave. In circuit Test only after post wave [2]. Knowing this we can determine how each of the possible defects can be captures to determine the optimum test coverage for each alternative.

Inspection and Test Methodologies

The main inspection and test methodologies used across industry are Manual Inspection, Automated Optical Inspection, Automated X-Ray Inspection, Boundary Scan Testing and In Circuit Test. The first three can be classified as Process Monitoring and Structural Test and the last two as Electrical Structural Test [1]. Typically, the first three options are machines available at manufacturing sites which are programmed to adapt for the different boards. The last two options are tailored specifically for each printed assembly board and required special test equipment. To be able to perform In Circuit Test or Boundary Scan testing, access is needed. Test access continue to be an issue, especially for in circuit test, which is fundamentally dependent on electrical access [3].

Test Coverage

It is important that each of the test methodologies is well understand and its selection is defined for each product, so a manufacturing test coverage calculation can be performed. There are three main standards to calculate test coverage, these main standards are PPVS, MPS and PCOLA. PPVSF was established by Aster Technologies and calculates coverage according to the following four parameters: Presence, Polarity, Value and Solder. On the other side, PCOLA which stands for the Presence, Correctness, Orientation, Live and Alignment parameters was established by Agilent Technologies. The last one and least used is MPS, established by Phillips Research, includes the parameters Material, Placement and Solder. These three main calculation methods include inspection and electrical testing on their formulas, one reporting format exist for each of them [1].

PROBLEM AND OBJECTIVES

The researcher investigated the issues encountered with the current Printed Board Assemblies Test Coverages by:

- Developing a method to calculate PBA Manufacturing Test Coverage that separates Inspection from Testing
- Differentiating Inspection and Test methods
- Understanding possible failure modes of electronic parts used on Printed Board Assemblies

METHODOLOGY

A survey was prepared to understand better how these methods are used and the current needs. The results were carefully reviewed and used to create a new method of calculating the Printed Assemblies Board Manufacturing Test Coverage. The questions included in the survey were:

- Role within the industry?
- Years of Experience?
- Which PBA Manufacturing Test Coverage Method is used across your industry?
- What are the advantages of using this method?
- What are the disadvantages of using this method?
- Do you think Inspection and Electrical Testing should be separated?
- What can be improved on the current method you use?
- Have you used other method? If yes, which one?
- What would you like to see if a new method is introduced?

The survey was administered to Test Engineers, Manufacturing Engineers and Design Engineers of

different Original Equipment Manufacturers, Product Suppliers or Test Equipment Suppliers. It was also provided to other individuals involved as well on the design, manufacture and test process of Printed Board Assemblies. The survey was sent to different individuals and individuals of different industries to understand better each persona needs and each industry needs.

Survey results were tabulated and analyzed to understand how they used the methods and generate a new method. This new method used as a starting point the current three methodologies. The end goal was to ensure that as much as defects as possible are covered while optimizing the test and inspection process.

Using the complex index that was introduced into electronics industries and which separate PBA complexity on 3 different categories: Low Complexity, Medium Complexity and High Complexity will be used on the future to test the new method to calculate Printed Assemblies Board Manufacturing Test Coverage. The results will be compared against what is expected from Test Engineers, Manufacturing Engineers and Design Engineers and expressed on the survey.

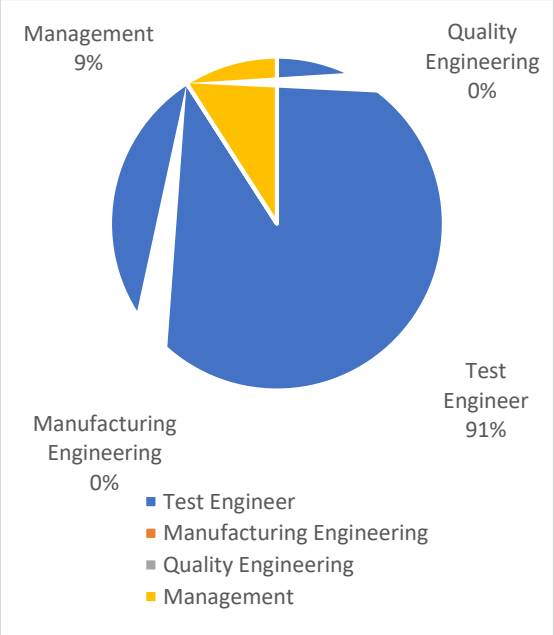

Figure 1
Participants Position at their Companies

RESULTS AND DISCUSSION

The survey was sent to around fifty Test Engineers, Manufacturing Engineers, Design Engineers and Managers of different Original Equipment Manufacturers, Product Suppliers and Test Equipment Suppliers. Eleven surveys were received, As shown in figure 1, 91% of the participants being Test Engineers and 9% Managers. With regards to the years of experience, as shown in figure 2, 64% of the responders have 10 or more years of experience.

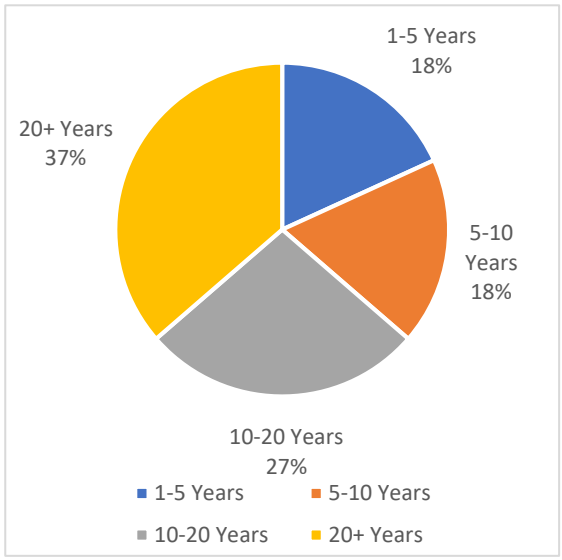

Figure 2
Participants' Years of Experience in the Industry

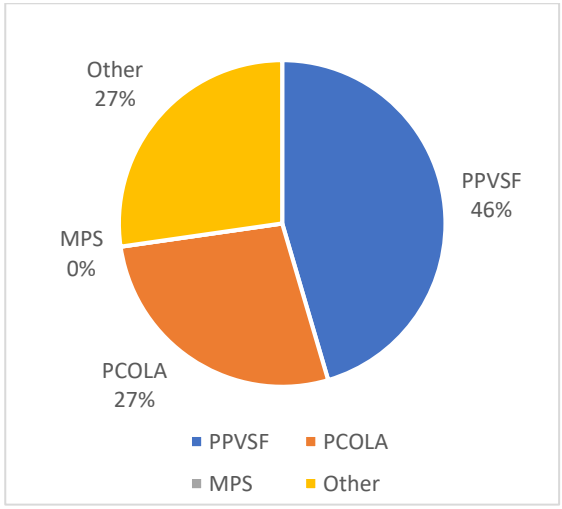

Figure 3
Test Coverage Methods Currently Used by Participants

Figure 3 shows the distribution of the different methods in use. PPVSF and PCOLA are the methods more used and being identified, several participants used other methods. These other methodologies were not identified by the participants. The MPS method was not used by any of the participants.

The users of the PPVSF methodology claimed that this is an easy to use method which helps provide a maximum test coverage. Most of the recommendations provided were with regards to the way it calculates weight and how to discriminate inspection versus testing. The advantages that the PCOLA methodology users identified are that is easy to identify manufacturing issues and covers a broad range of different ATE's and factors. Some of the recommendations on improvements for the PCOLA Methodology are to make it more automated and find a way to discriminate between inspection and testing.

When asked about the differentiation of inspection and testing, as shown in figure 4, 73% of the participants answered that it would be good to calculate those separately. Capability of altering coverage analysis manually to reflect current designs, differentiation between inspection and testing, new weight method and standardization were among the answers the participants provided for improvements on existing or on a new methodology.

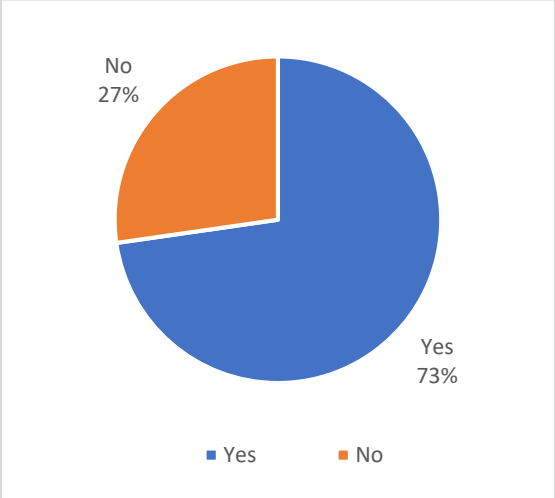

Figure 4
Participants Who Believe Inspection and Electrical Testing Coverage should be Calculated Separately

Table 1 shows all the responses from the participants.

Table 1
Improvements if New Method is Introduced

What would you like to see if a new method is introduced?
Capability of altering coverage analysis manually to reflect current design.
A method can analyze the real data with the theorical data and give to us good result.
It will be perfect to have a system that can-do optical inspection on components that are no easy to test like parallel capacitors while the board is being test. It will significantly reduce the product cycle time.
If a new method is introduced, I would like to see a differentiation of inspection versus testing or having weighed show that difference.
Standardize
Weight pins that can be driven high and low different than power and analog pins. (You can't drive a power pin high and low). In my experience, solder shorts are the most common defects found in ICT/FP tests and there must be a way to measure how good the coverage is for this, considering some adjacent pins may share the same nets. A separate metric maybe?
Companies agree to use it as an industrial method.
Sometimes non-PBA-test engineers prefer coverage from AOI and AXI because PCOLA seems to have the same coverage as FPT or ICT. So, something that would be good would be to give e weight to testing using FPT or ICT than AOI and AXI.

Participation Analysis

The response rate of the survey was 22%. Test Engineers participation was higher because they are the ones that perform this kind of analysis; therefore, they may feel more confident about answering the questions on the survey. Design Engineers and Quality Engineers although receives and analyzes the results may have decided not to participate since this is not their area of expertise. Also, participation may have been low since these analyses usually are part of their company standard operating procedures or maybe because they have their own methodologies and may have decided not to participate to not provide any information that may result on sharing company proprietary information. Having direct involvement of companies that

manufacture and test Printed Board Assemblies may have help on getting better participation.

Printed Board Assemblies Test Coverage Discussion

The majority of the participants were Test Engineers and as shown before with more than 10 years of experience on Printed Board Assembly Manufacturing it provides a broad spectrum of experiences with issues being seen from different angles. The inputs provided emphasize on the importance of having a method that is easy to understand and discriminates between inspection and testing, having a standardize method for which the industry agrees and having also a standardize weigh for components. This is important cause this way no matter which company you decide to request a test equipment, send your boards for manufacturing or use for inspection and test all of them will agree on a test coverage.

Printed Board Assemblies Test Coverage Requirements

With the results obtained three requirements for a new methodology can be established. As per the results obtained from the survey some of these requirements should be:

- Shall provide differentiation between inspection and testing.
- Shall differentiate also between inspection or processes that cannot be replaced by each other (i.e. inspection before soldering and inspection after soldering).
- Shall be standard across organizations.
- Shall include weight depending on complexity of the component.

Printed Board Assemblies Test Coverage Diagram and Formula

Using these requirements, a diagram was created to show how the formula could be designed (figure 5).

Figure 5 breaks down how the Printed Board Assembly components should be catalogued as per the individual processes. There are two major categories: Inspection and Testing. Under inspection there are two sub-categories which are pre-reflow (inspection before soldering) and post-reflow (inspection after soldering). Under these categories then we have the possible defects that can be detected under those processes which are Placement, Solder and Orientation. Under Testing we have then the possible defects that can be detected which are Value, Function and Live. A *1* means a component can be inspected or tested during that process and *X* means a component cannot be inspected or tested during that process. The possible defects were an *X* is shown should not be accounted in the formula as there is no way they can be detected. The formula will normalize the Test Coverage by just taking in consideration the components that can be effectively inspected or tested. The formula for inspection coverage and test coverage would be:

Figure 5
Printed Board Assembly New Methodology Structure

$$\text{Inspection Coverage}_{\text{PSO}} = \frac{Presence_{QTY1} + Solder_{QTY1} + Orientation_{QTY1}}{Presence_{Total-x} + Solder_{Total-x} + Orientation_{Total-x}}$$

$$\text{Test Coverage}_{\text{VFL}} = \frac{Value_{QTY1} + Function_{QTY1} + Live_{QTY1}}{Value_{Total-x} + Function_{Total-x} + Live_{Total-x}}$$

CONCLUSIONS

Engineers may have different criteria when doing their jobs, and this is the main reason a standardize methodology to perform their jobs is needed. While more companies go global and start using different companies to assist with the design, manufacturing and testing of their products, having a standard way to calculate Printed Board Assemblies Test Coverage is imperative. A new methodology that is easy to work with and easy to understand by Management and Engineers not involved during the Test Process is essential. Also, having formulas that don't integrate processes may ensure everyone, from engineers to management, understand correctly the information presented, and proper decisions are made when deciding to remove inspection or tests processes due to high cost or due to time constraints. Ultimately, the Test Engineer wants to ensure Maximum Inspection and Test Coverage, along with having an optimum Inspection and Test Flow.

The requirements and new methodology, ICPSO/TCVDF, proposed covers these aspects; however, it needs to be reviewed and approved by the industry to ensure standardization. Also, the industries need to agree on providing a weigh to the components to ensure complex components account for a higher percentage in the formula than components with less level of complexity.

FUTURE WORK

Future research may include proving the new methodology, comparing results with already existing methodologies, and discussing the results with industry experts. Also, a committee composed of industry experts should be established. This committee will ensure that there is agreement on the new methodology and that there is standardization on the way the PBA Test Coverage is calculated.

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