Automated X-ray Inspection Strategies for High Volume, Resource-Constrained Production Environments
Web Seminar – Tuesday, July 22, 2003
Questions & Answers

1. Can I get a copy of the case study that was presented to review the details more closely?

- A recording of the web seminar is available for download at the following link: http://www.teradyne.com/prods/cbt/products/library/general_lib.html

- A technical paper summarizing the case study and results is also posted along with the web recording. Use the following link: http://www.teradyne.com/prods/cbt/products/library/general_lib.html

- You can read about the NEMI Test Coverage Analysis Experiment in *Circuits Assembly* magazine, August 2002, page 35, or you may access the info by clicking here: http://www.nemi.org/newsroom/PR/2001/PR103001.html

2. Isn't transmission AXI test access board dependent?

Transmission AXI test access is board dependent on double-sided boards; access is 100% on single sided boards. Because the entire solder volume is inspected, and everything in the path of the x-ray beam is imaged at one time, solder joints that overlap each other in a top/down view of a double-sided board can be non-accessible. The programming software automatically determines which solder joints overlap one another and removes these from the inspection list. This type of modeling can be performed using Teradyne's Design-to-Build Strategist™ software early in the product design phase to determine test coverage and feedback design changes.

The data presented during the seminar shows a high-complexity, double-sided board with approximately 14,000 solder joints having 67% transmission AXI test access. This level of access was all that was required to deliver the same test effectiveness as cross-section AXI at 66% lower cost of ownership.

Transmission test access on double-sided boards can be as high as 95%; there are many double-sided board types that are well suited to transmission AXI strategies. Generic categories of boards like automotive, servers, motherboards. and hard-drive boards are a few examples. These board types exhibit high transmission AXI test access regardless of board-to-board variation and also tend to be built in high volumes that necessitate high PTE (Production Test Effectiveness).

There is no doubt, however, that cross-section AXI delivers higher test access on double-sided boards. The board types that tend to require close to 100% AXI access can often justify the high cost of the cross-section strategy. "High end" routers and telecom switches that are built in low volumes are examples of boards that need close to 100% AXI test access and can often justify the very high cost and slow inspection speed of cross-section AXI methods. These board types are not candidates for a transmission AXI test strategy.

Transmission AXI test access can be increased if the first side assembled is inspected prior to second side assembly. In this way, access will be 100% for the first side (because no components are yet populated on the opposite side), and some overlap will occur when the second side is inspected. This methodology also improves feedback to the line since there is no wait for second side assembly prior to x-ray inspection of the joints on the first side. All test access figures presented in the web seminar were for a single pass inspection process (both sides at one time), not the two-pass process described here.

3. Is it true that PTE (Production Test Effectiveness) does not include factors like time spent debugging boards at functional test?

It is correct that PTE does not include factors like time spent debugging boards at functional test; but neither does the TE (Test Effectiveness) metric. We should consider that the coverage of any test strategy is never 100% and that there is always an opportunity for more defects to be introduced further down the line. Test strategies that require very high resource levels to sustain them can also deliver much higher escape rates than originally projected due to a scarce supply of resources. The TE and PTE of the transmission strategy on Board 2 was 97% - this is equal to the TE of cross-section AXI at 66% lower cost of ownership.

We should also remember that process indicators will not fail electrical test and that all process indicators in the case study passed ICT under 100% node access. However, some defects can and will escape. To quantify the cost of these escapes and the cost of debug at functional test, the NEMI cost model (see question 4) and Strategist software can be used. If the current test strategy is ICT-only, however, it is clear that transmission AXI can offer significantly higher TE and PTE than the ICT-only strategy at a very economical cost. If you calculate that the additional TE that may or may not be offered by cross-section AXI is worth its very low PTE, then a cross-section AXI strategy may be the best choice for your product.

Some products will require cross-section x-ray strategies; these products are generally very high complexity, very high value boards that are built in low volumes. Manufacturers may wish to consider that both a transmission x-ray system and an AOI system can be implemented at about the same capital cost and resource outlay as cross-section x-ray. Perhaps a combined AOI and transmission AXI strategy can deliver greater test coverage on some types of high value boards than a cross-section-only strategy. The combined transmission AXI and AOI strategy will exhibit high TE and PTE figures whereas the cross-section AXI strategy will only exhibit high TE.

4. Will Strategist calculate the cost and ROI of a strategy?

Teradyne's Strategist software can help to quantify test strategies in the following ways:

- Calculate production defect spectrum using your DPMO data
- Pin and component coverage of every test machine for every defect type
- Defects found and not found by each machine
- DPMO entering and exiting each machine
- Yield at each machine
- Test time at each machine

The software can calculate these figures early during product design to facilitate DFx processes. The software also helps deploy the test strategy to the production floor by creating the input files required to program each test system. Finally, the software can "read back" the debugged test programs to verify whether the test coverage achieved in production matched what was predicted during design – this creates a closed loop cycle.

Strategist does not currently calculate the dollar savings of a test strategy; however, the output reports from Strategist can easily be input into a cost model tool that has the various labor rate assumptions that are applicable to your manufacturing environment. The NEMI Test Strategy Team created a cost model spreadsheet. You may find this cost model useful in calculating the cost of test strategies. To read more about this cost model or to obtain a free copy, visit:
http://www.nemi.org/projects/TSCM/test_strat_cost_model.html

5. Do you have a PPM rate to justify slide 9 (out of focus joints on cross-section AXI cause false calls)?

Yes. A good reference for typical performance rates with cross-section AXI, including PPM false calls, is available in a technical paper that was written jointly by persons from Celestica, Solectron and Teradyne. The paper was presented at the APEX 2002 conference and is titled "Continuous Improvement Strategies for Automated X-ray Inspection" by David Mendez, Chris Shirley and Amit Verma. Failure rates are discussed on pages 2, 3 and 4. You may obtain a copy of this paper by clicking here: http://www.teradyne.com/prods/cbt/products/library/xray/axi-continuousimprovement.pdf

6. I did not know that AXI thresholds were dependent on programmer interpretations. Is AXI better than human inspection?

Although programs written by two different people will deliver conflicting results, there is still much improvement and cost savings over the human visual inspection method. The person-to-person variability is reduced to 2 (?) persons (who are programmers) as opposed to the 15 or 20 persons that would be required to visually inspect the same number boards. The machine is also more consistent from hour-to-hour and day-to-day. The x-ray system can see many more details in the solder joint than human inspectors can, and we should remember that although the programs require subjective interpretations by programmers, many quantitative and repeatable measurements are also part of the AXI technique. Manufacturers can achieve significant savings with AXI; however, it is important to keep the limitations of automated inspection systems in mind before implementing them in a production environment.

7. What is the NEMI Test Strategy Project?

NEMI stands for "National Electronics Manufacturing Initiative". It is a consortium of companies that work together on new technologies and processes in a collaborative environment. You can read more about NEMI on their website at www.nemi.org. To read about the NEMI Test Strategy Project, click on the following web address: http://www.nemi.org/newsroom/PR/2001/PR103001.html

8. What is the IPC Subcommittee on Automated Inspection Technologies 7-32?

The subcommittee has two initiatives underway:

- **Test Vehicle Project – Leader: Amit Verma, Teradyne (co-chair of subcommittee)**
  This team will work toward translating IPC 610 solder joint acceptability criteria into a language that is directly measurable by automated inspection machines. The team will collect inspection data from AOI, AXI, and visual inspection methods and correlate the results to the reliability of lead-free joints via thermo cycling. The team will work closely with the NEMI lead free project and the IPC 610 Subcommittee.

- **Equipment Evaluation Criteria Project – Leader: Steven Perng, Solectron (co-chair of subcommittee)**
  This team will create a new revision of IPC AI 641A. This document defines the key performance criteria for automated inspection equipment. The team will define what key metrics apply to AOI and AXI machines both pre- and post-reflow and describe the methodology that both manufacturers and equipment suppliers should use to measure and report performance of equipment during an equipment evaluation study.

The 7-32 subcommittee meets on a monthly basis and is open to your participation. To join please contact one of the co-chairs listed above or contact: **johnperry@ipc.org**

9. Do you have a feel for how lead free boards are inspected with AXI?

Lead free boards can be inspected with both AXI and AOI machines. The same AXI machine program cannot inspect both eutectic and lead free boards, because the set-points are different. There are some technical papers that are available on the topic of AXI of lead-free joints. For a copy of these papers contact **amit.verma@teradyne.com**.

Also note that the IPC 7-32 subcommittee is studying lead free joints (see question 8 above).

10. Can you combine transmission and the cross section inspection in the same machine?

Yes, it is possible to combine both transmission and cross-section techniques into one machine. Teradyne's Digital Tomosynthesis AXI system uses both transmission and cross-section AXI techniques.

Digital Tomosynthesis is a computational method that creates cross-section slice images digitally via software. Laminography, by contrast, acquires cross-section images by the synchronous mechanical motion of many parts inside the x-ray machine.

It is important to note, however, that the transmission technique in the digital tomosynthesis machine runs at a much slower inspection speed than the transmission technique in the transmission machine. Therefore, although Digital Tomosynthesis does offer some of the performance benefits of transmission AXI, fast inspection speed is not one of benefits. For this reason, transmission AXI systems are best suited to high volume resource constrained production environments. Cross-section machines, like digital Tomosynthesis and laminography, are today constrained to offline, low volume production environments that can justify the high cost of cross-section x-ray.

11. Can Teradyne offer a cross-section AXI web seminar for the future?

Yes, a cross-section AXI web seminar will be offered in the future. In the meantime, for more information on cross-section AXI, please contact amit.verma@teradyne.com