Choosing the Most Effective Automated Test and Inspection Equipment to Maximize Fault Coverage While Still Optimizing Costs.

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In today's manufacturing environments, optimizing manufacturing costs and, especially Test and Inspection costs are high on most company's agendas. Resources are tight and many employees have multiple roles to fulfill across the whole manufacturing line so, time is limited. Test suppliers need to provide a suite of tools to ensure the highest level of quality for customer shipments.

Understanding the benefits and defect coverage provided by the many solutions is key to achieving the highest quality at the lowest costs and to select the best test and inspection strategy to use in manufacturing.

Most manufacturers I have worked with use the same techniques for test as have always been used: ICT, followed by AOI or Visual Inspection, followed by Functional Test and then system Test. Is this the most efficient way to ensure process quality and provide the lowest costs? No. In most cases tests are being repeated and costs are higher than they should be.

If we look at today's manufacturing processes there are a plethora of automated test and inspection techniques available to find defects, add quality and value: In-Circuit Test Systems (ICT), Flying Probers (FP), Manufacturing Defect Analyzers (MDA), Automated Optical Inspection (AOI), Functional Test (FT), Boundary Scan (BScan), and Automated X-Ray Inspection (AXI).

Each platform has capabilities that allow for different defect spectrum to be located, all at different cost points and diagnostic resolution. So, the question is, which solutions should I use to meet today's SMT Assembly challenges?

Defining a Test Strategy for today's manufacturing processes:

The first aspect of defining a test and inspection strategy is to understand the defects you are producing and what quality levels your customers demand.

Package Type	Pitch inches/mm	Structural DPMOJ
Leaded	> 0.05/1.27	200
Leaded	0.05/1.27	500
Leaded	0.025/0.64	700
Leaded	0.02/0.5	1000
Leaded	0.016/0.4	10000
Leaded	< 0.016/0.4	15000
Jlead/QFN		300
BGA/CSP	0.05/1.27	100
BGA	< 0.05/1.27	150
CGA		100
1206		400
0805		150
0402		150
0201		200
01005		300
SMT Connector		2000
Res/Cap Pack		100
PTH		2000

Figure 1 – Typical DPMO Rates

The component types, board densities, and process equipment used drive the quality of your final assembly. DPMOJ rates (Defects Per Million Opportunity per Joint) for today's packages range from below 50 DPMOJ to greater than 15,000 DPMOJ, with Area Array packages being the most reliable to place and reflow, while fine pitch leaded devices commonly having the highest DPMOJ rates. Figure 1 detail the typical DPMOJ rates that manufacturers experience. If you are a member of iNEMI or IPC there are many tools available for you to calculate the capability of your process, expected

yields and defect rates. For test and inspection it is important that your system capability matches your processes capability to deliver the highest yields.

System Capabilities: what is the cost to capture a defect?

Shown in figure 2, each of the test and inspection tools that can be deployed in a manufacturing process has different sets of capabilities and costs associated with them. Some such as ICT and Flying Probe can add value to the manufacturing process by programming devices. Lets discuss the options available to manufacturers today.

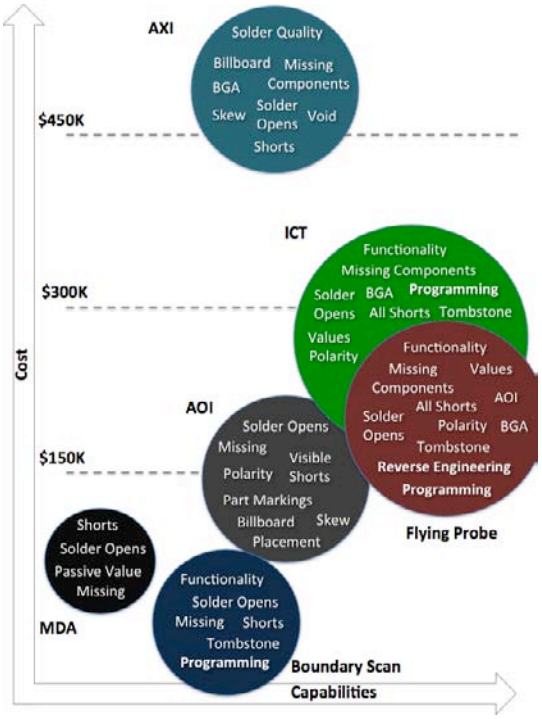

Figure 2 – Typical Costs vs. Capabilities
(Capabilities are based on Digitaltest systems. Prices are general, but typically sit in these ranges)

In-Circuit Test (ICT) and Manufacturing Defect Analyzers (MDA)

ICT is one of the most commonly used tools to find defects in a manufacturing line, but how well does it really perform in today's manufacturing environments? One of the key features of an ICT system is the fact it can provide device function coverage for digital devices. It can also program devices adding value to a product.

All digital devices can be tested using powered functional test, using boundary scan or BIST or using the common capacitive opens techniques, taking the capabilities to a lead only test. Dependent on the measurement capability of a system, the values all passives can be measured. The advantage of ICT is all electrical shorts, opens are found, devices are functional and parts are the correct value, and the product will function. And can still provide the fastest throughput in most manufacturing environments.

Today, dependant on configuration, systems ICT systems range from below $50,000 to over $500,000. When looking at ongoing support costs, ICT system will need a fixture and program, which needs to be considered for the overall cost of the platform.

Because of its overall test capabilities and speed, ICT is still used in most high volume manufacturing environments.

Flying Probe (FP)

While removing the cost of fixturing, flying probers have grown into very capable Test Platforms providing the most capability of all test systems on the market. For Example, Figure 3 shows the Test and Inspection of Digitaltest's Condor platform.

Analog	Digital	Inspection	Programming	CAD/CAE
Shorts	Vector Testing	Presence	I^2C	68 CAD formats
Opens	Boundary Scan	Absence	Flash	
Values	Memory	Position	CAN	
Polarity	BIST	Part Markings	All Propriatry	
	Nand-Tree	Polarity		
	Opens Check	Billboard		

Figure 3 – Flying Probe Capabilities
(Example from Digitaltest's Condor Flying Probe System)

The capabilities of todays flying probers cover all ICT, Digital, Boundary Scan, device Programming and inspection. So with better test and inspection capabilities and you don't need any fixturing is there a down side, yes cycle times. Dependent on your products these can range from 30 seconds to 5 mins per product. But there are ways the flying prober manufacturers have improved this. For example, Digitaltest's Condor system will allow you to probe major nets from the other side of the board significantly reduce test time or to add a small fixture to probe multiple nets, getting the cycle times very close to that of ICT, and exceptionally useful in high volume environments where you have loss-of-access.

Systems typically sit in the $220-260K range and can very quickly provide a ROI in < 1 year.

Automated X-Ray Inspection (AXI)

Two major types of 3D in-line AXI systems are available in the market today. These systems are based on Tomosynthesis and Laminography. AXI can provide the highest level of lead based inspection coverage, but have a number of issues associated with providing this coverage. Normally a 3D AXI platform will range between $450-750K, in most cases they are unable to meet line cycle times and can provide false calls above the 5000 ppmJ range.

Programming can be complicated and slow, as the varying track densities of the PCB substrate can affect each joint causing the programmer to treat many joints as separate items (Sub-Joints).

Today unless you are specifically looking very explicit solder defects on very high cost products, it is not a viable option for most manufacturing processes because of costs and throughput.

Boundary Scan (BScan)

As part of the Joint Test Action Group (JTAG) boundary scan became a standard in the 1990s, showing great promise. But the adoption of boundary scan was slow until recent days where loss of electrical access has become an issue with ICT and MDA systems. Boundary Scan, when implemented, provides a very high level of digital fault coverage at a low cost per defect, with solutions ranging between $10,000 and $45,000.

The key to Boundary Scan is to ensure your circuit design engineers take into account the capability. Most larger scale integrated circuits today include Boundary Scan. If your design engineers chain these devices together correctly, Boundary Scan techniques can provide very high fault coverage. Boundary Scan is one of the best tools in the industry today for digital device coverage, ISP and flash programming.

Automated Optical Inspection (AOI)

AOI systems provide quick programming and good cycle times, but defect coverage (especially opens coverage) varies greatly across platform and is affected by high false call rates. So choosing the correct platform is key to AOI working.

There are two types of systems one uses a template or golden image of a component and compare the part to the component under inspection to provide Pass/Fail information. The focus is predominantly on placement, presence/absence, and optical character recognition. These techniques can provide a quicker initial program, but has the issue of decreasing performance in production, as variations in your process have to be taught as you see them in production. Thus creating high false fail rates per board. These types of systems can generate programs very quickly for first article inspection but provide significantly reduced performance and risk in production.

Measurement based AOI systems provide far better defect coverage, lower false call rates and process information such as placement information, skew, trend analysis but need higher skilled operators to program the systems.

Choosing the Correct Test Strategy

Figure 4 details the total test coverage for each type of test and inspection scenario. As discussed previously, all test solutions have different capabilities and attributes. Consequently in today's environment, where quality and cost are key, you need to choose the best Test and Inspection solutions to meet your manufacturing needs. Clearly ICT and Flying Probe Test systems provide the highest fault coverage and can be complemented by a number of different solutions such as boundary scan.

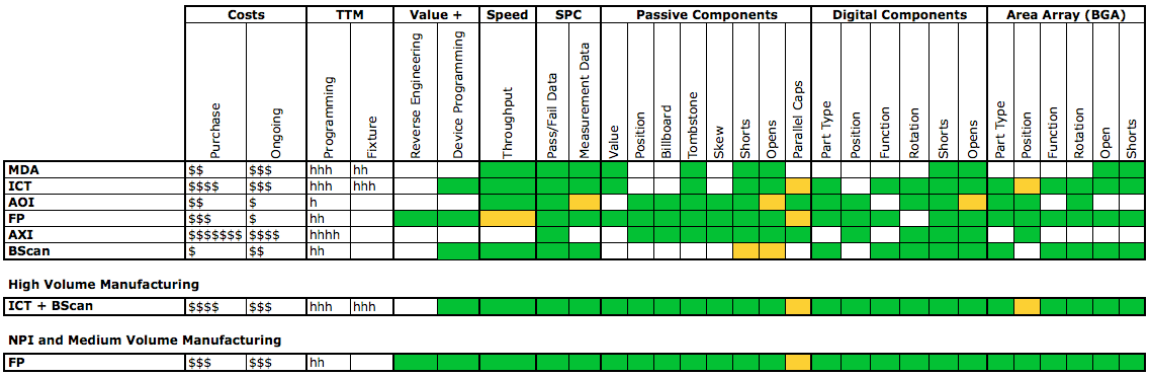

Figure 4, Fault Coverage Capabilities, NPI and High Volume Manufacturing

If you are in a NPI or low to medium volume manufacturing and have quality in mind flying probe systems such as Digitaltest's Condor, with its multiple test capabilities can provide the fault coverage you need, while minimizing ongoing fixturing costs. If you are in a high volume environment still the ICT such as Digitaltest's Sigma combined with Boundary Scan from manufacturers like JTAG, Corelis, TI Asset, Goepel can allow you to achieve the highest fault coverage.

Costs can also be reduced if you deploy systems with device programming capabilities, which in-turn can reduce costs and add value.

As all test and inspection professionals know many combinations can be used, but the obvious winner for fault coverage, while still providing the ability to meet high volume requirements is ICT or ICT combined with Boundary Scan. For the highest fault coverage in a NPI or low to medium volume environment Flying probers with the capability of the Condor system can provide the best fit.

As with any test strategy the goal is to match your quality and cost requirements with the best-in-class tools to meet these requirements.

Digitaltest's Product Portfolio.