HOW TO IMPLEMENT FUNCTIONAL TEST IN AN AUTOMATED ENVIRONMENT

Robert Stasonis
GenRad, Inc.

INTRODUCTION

In the past, testing of Electronic subassemblies has been a separate function from the manufacturing process. However, due to increased productivity demands, personnel limitations and Quality issues, it is now an accepted fact that ATE can be integrated into an automated electronic assembly line. Reduced operator intervention, automation of quality data logging, and improved productivity are all well understood. However, testing in an automated environment provides new challenges, or opportunities, for both the ATE vendor as well as the end user, many of which are now just becoming understood. This paper will examine some of the questions you have to ask prior to selecting a vendor and implementing a functional test strategy.

Questions, Questions…..

As I stated earlier, adding test to an automated assembly line is not a simple matter. There are questions for both the end user as well as the ATE manufacturer (Automated Board Handling is a relatively new art to the ATE industry) to consider. As a manufacturer, the issues to consider include the following:

- Is the ATE of choice compatible with hardware in your assembly process? SMEMA Compatibility is virtually mandatory if you want the system to interface with the other portions of the line. Fortunately, most vendors do support this standard.
- What type of testing (e.g., Vision, MDA/ICT, Functional, etc.) is best suited for my expected Fault Spectrum? In most cases, a combination of all three should be considered, especially in light of the short product life cycles seen today. This test strategy provides access to all aspect of potential faults at every stage of the process. As a new products comes on line, you have to look at similar manufacturing-induced faults seen previously, at least for the short run. Given the short product life cycles typical today and you virtually have to mandate a Manufacturing defects test strategy, as a minimum, as well as end of line functional. Programming preparation efforts and times for each ATE type must also be factored in.

- It is important to remember that in an automated as well as a manual testing environment, the ATE's "Throughput", which is also known as test time, and handling times must be considered. While the total time will be much shorter with automation, they still have to be kept in mind. If the beat rate of the line is faster than the ATE's throughput, either additional ATE hardware has to be considered or a modified test philosophy is required. You can no longer push test off to a later time.
- Communications with other systems that control the assembly process. Can the ATE selected communicate with other systems in the assembly line to monitor and even assist in improving the efficiency of the manufacturing process?
- How much additional auxiliary equipment, such as Input/Output Buffers & Shuttles to move UUTs to and from the ATE, is needed to support the ATE?
- Floor Space – As you will see in this paper, depending upon the technology tested, throughput and the line's beat rates, multiple ATE systems may be required. In an automated environment, you can't just let product pile up and let the third shift test them. NOW is the watchword.
- New ROI and line flow models. Your test and repair philosophies will shape this requirement.
- Test Engineering and Operations must work together more closely to successfully select and deploy ATE. New design requirements for <u>Automated</u> testing come into play.

While the "A" in ATE means "Automatic", this letter rarely applied to the board handling in the past, but rather the automating of the actual test process. For this reason, ATE vendors have their own issues to consider, including;

- Developing an understanding of automation.
- Develop partnerships with automation vendors in order to design a compatible automation product. As the automation vendors already have a wealth of knowledge on the subject and the requirements, ATE vendors are leveraging this expertise and knowledge.
- Developing faster and more efficient throughput algorithms. Test times become more critical as you can only buffer product for so long in an automated environment without human intervention.
- Understanding the needs of Manufacturing Operations management. Selling ATE to an automated environment brings other customer personnel into the decision making process.
- In the case of Functional Test, develop a philosophy that focuses on JET, or Just Enough Test. The statements means that the actual functional tests performed in line should be evaluated on the basis of detectable faults compromised by line beat rates. Because of inherent delays built into a product, functional test can be much longer than In-circuit test. In order to minimize the impact of beat rate, and limit the number of testers needed on the line, these choices are critical.
- Updating ROI models to reflect automation issues.

Clearly, both the vendor and end user have some homework to do. In this paper, we will elaborate on many of the parameters that end users have to include in their decision making. While many of the requirements will be second nature to you or your department, you may be surprised by several of the considerations here.

For the purposes of this paper, we will focus on the area of Functional Test. This is because each method of testing has its own requirements and justifications. To discuss all areas would either reduce the depth of this presentation, or turn it into a complete, albeit lengthy, volume on test. But you will find that many of the recommendations presented here for functional test can be applied to any test strategy.

Also, it is important to note that ROI considerations are not mentioned in this paper. This subject alone would fill volumes in itself. But be assured that the questions brought up in this paper need to be answered **before** any return on investment calculations are made.

Why Functional Test?

While this paper is meant as a discussion of where and how functional test can work in a high-volume manufacturing environment, you need to ask "Why" first. Today's Surface Mount Technology is limiting access to test points and providing bus speeds that are beyond the reach of present In-circuit technology. Such issues are making testing via In-circuit a limited solution. In addition, vision testing will only tell you if the components are there, oriented correctly, and possibly that the solder re-flow was correct. While all of this is important, you still need a functional test to insure that the components work together.

If your technology includes RF and Wireless circuitry, you have another issue. The values of many of the components in the Transceiver portion are so small that they can not always be measured accurately using In-circuit techniques. The best you can often hope for is verification of the presence of these components. The only way to ensure that this circuit is assembled properly is to do a functional parametric test of the circuit.

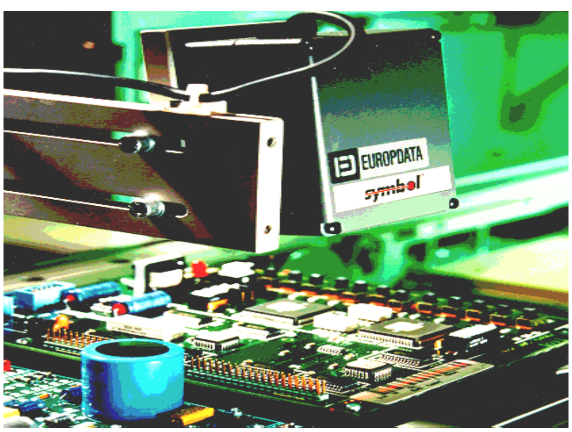

Fig. 1 - Automation allows for automatic scanning of UUT Bar Codes. In the case of Panelized UUTs, it may be desirable to serialize the panel itself, with the UUTs serialized after they are broken up. (Photo courtesy of Symbol Technologies)

End of line functional test can also simplify the recording of calibration and performance data for ISO 9000 and FDA requirements. As this information is mandatory for compliance in these areas, automation greatly simplifies a tedious task.

In many instances, a good functional test, with properly collected data, allows the manufacturer to ship product directly from the production line. The cost savings here can be quite substantial, helping to payback the investment in test very quickly.

Automation also lends itself well to what is known as "Paperless Repair". UUT serial numbers are collected automatically by the test system (Fig. 1). Failure analysis is logged automatically and forwarded to the repair station via a network. This eliminates the possibility of repair tags getting lost or swapped accidentally and assures that the correct failure data (and in many cases, good UUT data) is available for the Quality and Repair departments.

Functional Testing Considerations

As stated previously, there are a number of issues to be considered before automating your testing philosophy. They vary, depending upon such issues as the technology to be tested, production volumes, budgeted allocations for test, and many more. For purposes of clarity, let's look at each of the areas of technical justification. The areas highlighted are not necessarily in any specific order as each manufacturer will have different priorities. But all of them must be considered for the best return on ATE investments.

Fault Spectrum

All product designs will exhibit faults, either design or process induced. These potential faults must be analyzed and a determination made as to what is the best test philosophy to detect them. This process should be considered in advance of volume manufacturing. Detection of the type, magnitude, and anticipated quantity of faults will dictate the required test philosophy.

In the sample shown in figure 2, over 75% of the faults present on the UUT were directly attributable to Manufacturing defects. Only 14% of the problems are caused by defective components or ESD handling issues. But prior to functional test, the vast majority of these should be weeded out by test philosophies aimed at these problems.

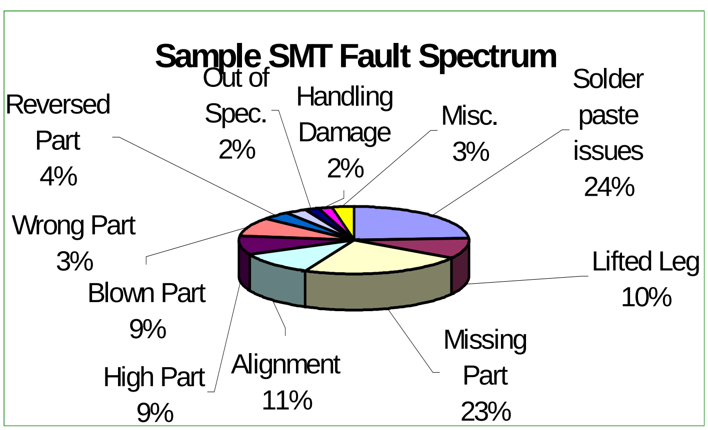

Fig. 2 - A typical Fault spectrum on an SMT assembly line. The types of faults and percentages will vary depending upon factors such as line maturity and technology manufactured.

Of course, this fault spectrum carries less weight if the number of UUTs exhibiting these faults is extremely small. While a test philosophy must be aimed at detecting particular faults as soon as possible, economic justification must take precedent.

In any case, by the time the UUT reaches functional test, the majority of manufacturing defects should be eliminated. This is because Functional Test can typically detect only one fault at a time. As one fault can propagate false failures throughout the UUT (e.g., a defective clock can cause all of the UUT to appear to be defective.), this can create a “Shopping List” of alleged faults. If your process is relatively mature, thus minimizing the number of process induced faults, then functional test can be implemented without an In-circuit test earlier in the process. Functional test should also be considered when addressing performance testing, certification, and calibration issues.

Minimum Test Requirements

Your first question here is not “Should I test?”, but rather “How much test is enough”? As a functional test must take into account the normal operating delays inherent in the UUT design, a complete functional test may take too long and can slow down the line. A good example would be a Cellular Phone. These devices take three seconds or more to power up and complete self tests. That is at least three seconds where you can do no testing….. Yet the manufacturing line keeps producing irregardless of the delays. So these inherent delays may limit the amount of testing you can do before the next UUT is presented to the ATE system for test.

One solution here is to carefully select those tests which will accurately eliminate the majority of performance problems that could occur. Based upon known design issues and interoperability guidelines, which is defined as the UUT’s interaction with other known hardware from multiple vendors, the minimum number of tests for an desired quality level can be determined.

Another alternative is additional test stations, magazines and conveyors. But all of this additional hardware adds cost and floor space to the assembly line layout.

When confronted with the need for testing large quantities of UUTs in parallel, one compromise strategy to consider is to select a Functional Test System that supports “Concurrency”. This feature allows for multiple UUTs to be tested at the same time. This method can mean that inherent UUT delays are more than offset in time by the testing of multiple UUTs. As an example, a major modem manufacturer applied the Concurrent Test Philosophy on their manufacturing line, testing eight modems simultaneously. Four Modems are tested for parametric functionality (i.e., amplitude, distortion, etc.), while the other four are tested for functionality (e.g., DTMF, synchronization, BER). The net result was that the total test time for the eight modems turned out to be less than the beat rate of the manufacturing line! This meant that one tester, and a loader to queue the eight modems for test, could serve one manufacturing line.

Certification

If your products address “Mission Critical” industries such as the Military, Aviation, and Medical, you don’t have to be reminded about the issue of certification of your testing. Fortunately, an automated functional test can address many of these requirements.

If your UUTs are serialized during the assembly process, testing by a system that supports datalogging, should be considered. If so, several requirements must be examined. The datalogging format capability should be easily configured so that the reports need minimal or no editing to meet quality requirements. Networking support is mandatory to simplify the gathering of the test data. In this case, automation eliminates the human error factor. Serial Numbers are automatically read by the system and pass/fail data for the UUT is stored.

And of course, Certification Testing precludes my “How much testing” question raised earlier. If a parameter must be measured and certified against specifications, then there is no choice. This can mean that additional ATE systems are required if test times get too lengthy. As stated previously, a system that supports Concurrency here may save valuable floor space. No matter which philosophy your company chooses, in the end you will likely find that the improved handling times and reduced operator intervention will help justify the investment.

Where to Test?

This may sound like a strange question. But in some products, you have to determine whether to do functional test before or after final assembly. For example, a PCMCIA modem would likely be tested before encapsulation as the packaging is usually designed for protection and low cost….. But not for re-work. It is better, in this case, to fix performance faults prior to the encapsulation stage. Testing prior to encapsulation is also a good choice for panelized applications.

Panelized UUTs can be tested concurrently prior to routing and separation. Such a strategy makes handling the UUTs in the ATE system much easier as well and the panel tends to be structurally stiffer.

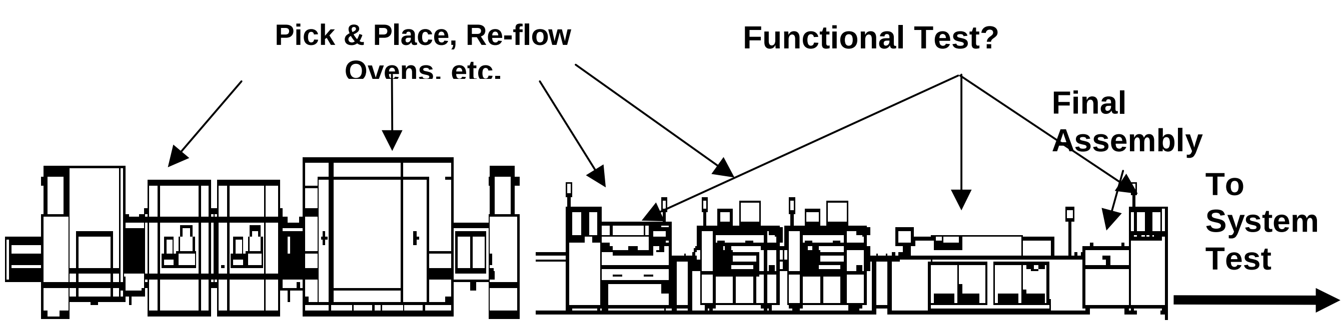

Fig. 3 – Where you test can be just as important as if you test.

Defect Disposition

Failed UUTs in an automated environment adds an additional requirement -- Namely, what to do with the bad devices? The quantity of defective UUTs will vary on a daily basis. This is due to the addition of random, accidentally induced faults, which cannot be accurately predicted. Such faults could include wrong components installed on a pick and place system, and not subsequently verified by In-circuit test. In any case, adequate in-line reject magazines, or operators monitoring the process need to be considered. Again the Paperless Repair strategy is a good fit here. Figure 4 is just one example of how to implement defect disposition.

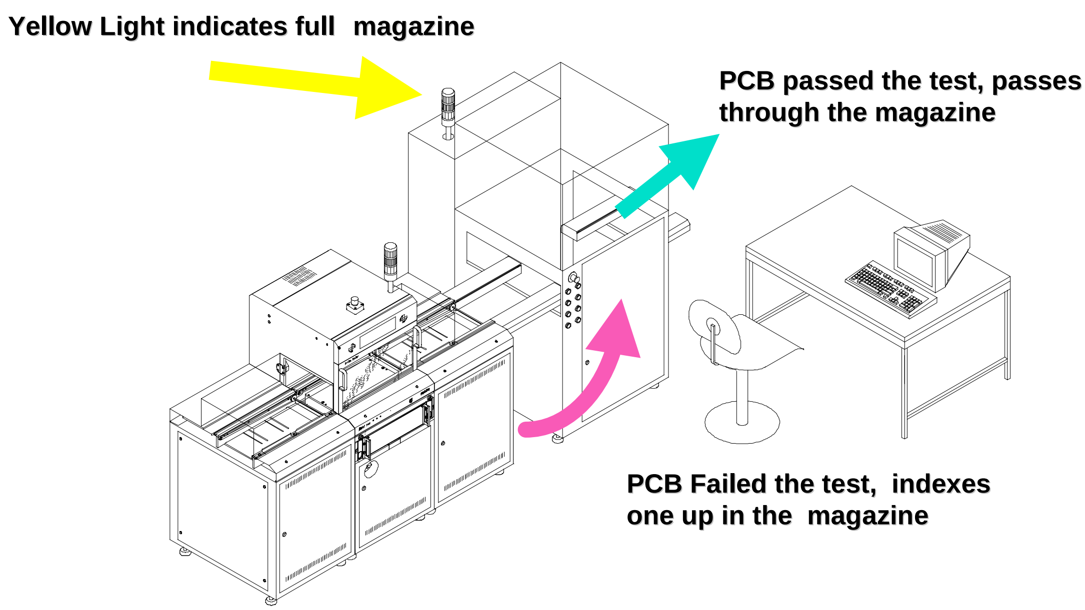

Fig. 4 – This diagram is an example of a failure magazine strategy

Insight

When implementing test in an automated assembly, you have an opportunity to do far more than just test. As each system (ATE, Pick-and-Place, reflow, etc.) can communicate to a central process monitoring site via a network, we can look at test to spot process problems in real time. In this way, we can stop a production line before hundreds, or even thousands, of subassemblies are manufactured with an easily solvable defect.

By networking all of the processes in your manufacturing line, it is also possible to look closely at utilization of all of the systems in the line. According to NEMI (National Electronics Manufacturing Initiative), the average utilization of the various elements of an automated assembly line is **less** than 50%! Careful review of each system may open up ways to improve the overall efficiency of the line.

Another advantage from this “Insight” may be found in test times. For example, an ATE system can be set to eliminate tests of stable portions of the UUT until a “Significant Event” occurs. This event might be an operator changing a reel of components on a pick-and-place machine. If the operator put the wrong component reel on the machine, this component would effect the circuit that is presently not being tested. Communication between the pick-and-place machine and the ATE would allow testing only when necessary. Once a statistically significant number of measurements have been made on the circuit, we can be certain that it is being assembled correctly, and the test can again be eliminated. This can result in significant savings in test times during stable periods in the manufacturing cycle.

Integration Decisions

Once you decide to add functional test to the process, one final decision must be made. That is, what functional test system should be applied to our process? Now it is not our intention to broach the subject of vendor choice here. But we can help with one issue.

Fig. 5 – When Integrating ATE systems, you have the choice of adding a handler to an existing system (middle) or purchasing a completely integrated system (right). There are several factors to consider before you make your decision. (Photo courtesy of ITE)

You can elect to do the integration yourself. In other words, you can take your existing functional test, or purchase a commercial system, and interface it to the handler of your choice. This allows you to potentially take your existing test strategy and integrate it, saving future development charges. You have the option of building the system that best fits your environment.

The downside can be the length of time for the integration, especially if you do not have staff that are adequately trained. Also, there can be issues of cabling, due to mechanical incompatibilities between the ATE of choice and the handler. This can add undesirable cable lengths, which in a high frequency application, can potentially compromise test capabilities.

The other option is to find an ATE vendor that offers an integrated solution. The advantages are quick integration of the hardware into your manufacturing line as it comes from the Vendor's factory ready to install. In many cases, the ATE hardware is very close to the test fixture, assuring signal integrity. The potential downside is that previous Test program developments may not be reusable.

Case Study

This example relates to an automotive electronics manufacturer. The unit being assembled is a body controller. This unit controls features such as power windows and locks, warning alarms, etc.

In their original manufacturing philosophy, only MDA testing was done in the line. All functional testing was done after the unit was fully assembled. In a 2-up panelized configuration, the beat rate of the line is 45 seconds.

When you look at the potential fault spectrum of the UUT, there were several problems with this concept. First, as the units are conformally coated, diagnosis and rework after coating is difficult and expensive. Also, as the number of UUT options that can be enabled vary greatly, the UUT’s EEPROM was programmed on the line. The program could change many times during the day as different lots were produced. Therefore, it was important the EEPROM be verified prior to coating. Another fault condition related to opens in areas that had no bed of nails access. So these faults could not be detected at the MDA level.

An in-line functional test system was added immediately after the MDA test. Because of limited space in the line, a handler was mated to a commercial functional ATE, as the commercially available systems were too long. The MDA eliminates as many manufacturing defects as possible. Faulty UUTs are logged and routed to a repair station in the line. As these UUTs are repaired, they are placed back in the line to be verified prior to functional test.

Faulty UUTs at Functional test are shuttled off the line for diagnosis before they could be encapsulated. This path was chosen as it was felt that the longer diagnosis times for Functional test were not acceptable in the line itself.

The test program had to deal with the issue of long delays inherent in some of the features of the UUT (Example – 30 Headlight turn off Delays) by utilizing the serial port of the microcontroller to set up conditions and bypass delays.

The end result of the change in philosophy was a virtual elimination of diagnosis and rework issues in final test. The payback to the manufacturer of the change to the line was less than 6 months.

Conclusion

Once you have decided that Functional test will work for your process, now the task begins to select the type of test system and vendor to use. Like the subject of this paper, ATE selection is always a complicated process. But it is further complicated by the automation factor. Add in the philosophy of build it your self, System Integrators, packaged commercial solutions, etc……. and you have many choices. But a well implemented test philosophy, coupled with the right vendor and system, and a good ROI, can help you compete in today’s high technology environment.

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Biography

Bob Stasonis is the Product Marketing Manager for GenRad's GENEVA Family of Functional Test Systems. Over the last 20 years, Bob has held Technical, Sales & Marketing positions with GenRad, Schlumberger, and Wayne Kerr. He has written numerous papers and articles on the subject of Electronic Test.

Bob is presently the Vice President of Marketing for the American Society of Test Engineers (ASTE), secretary of the VXIbus Consortium, secretary of the Boston chapter of the IEEE Instrumentation & Measurement society, and US Marketing Director for the PXI Alliance.