A Look Inside
Automated X-Ray Inspection

by Rick Roth, Lectronix, and Don Miller, YESTech

AXI is an effective technology for finding manufacturing defects in electronics assembly operations.

Manufacturers of advanced electronics products know that simultaneously producing a cost-competitive product and meeting or exceeding their customers' quality expectations are vital to success. For these manufacturers, automated X-ray inspection (AXI) is becoming increasingly popular because, like its counterpart automated optical inspection (AOI), AXI is a noninvasive inspection solution.

X-ray images of solder joints can be automatically analyzed to detect structural defects such as insufficient solder, voiding, shorts, and opens that typically account for approximately 90% of the total defects on a complicated board. But unlike AOI, X-ray imaging is not hindered by ball grid array (BGA) devices, component shields, heat-sinks, and high-density double-sided boards.

This key advantage of finding hidden defects makes AXI the logical choice for inspecting complicated boards with BGAs, CGAs, CSPs, or components under RF shields. The increasing popularity of array-style packaging is impacting a very large number of boards today.

Many cell phones and wireless communications products are placing RF shields over unsoldered components at pick-and-place, using the reflow processes to solder them to the board. X-ray inspection is the best way to detect solder defects that are obscured by these shields.

In-line inspection during surface-mount assembly is most valuable when used to locate defects close to the fault source. This strategy enables quick detection, correction, and enhanced process control. Inspection cycle time also is critical for in-line AXI systems and must be fast enough to do the job within the allowed time while accurately verifying correct assembly and identifying errors.

AXI can be useful at many stages of the assembly process, but time and resource constraints usually limit most products to a single X-ray inspection. For that reason, it should be implemented where it will provide the maximum benefit to the process. Since automatic analysis of finished solder joints is AXI's strength, most systems are placed after the solder process, whether wave or reflow. At this point, all solder joints on the board are present and can be covered in a single test. Also, by waiting until the completion of the assembly process, any other defects such as damaged or missing components will be detected (**Figure 1**).

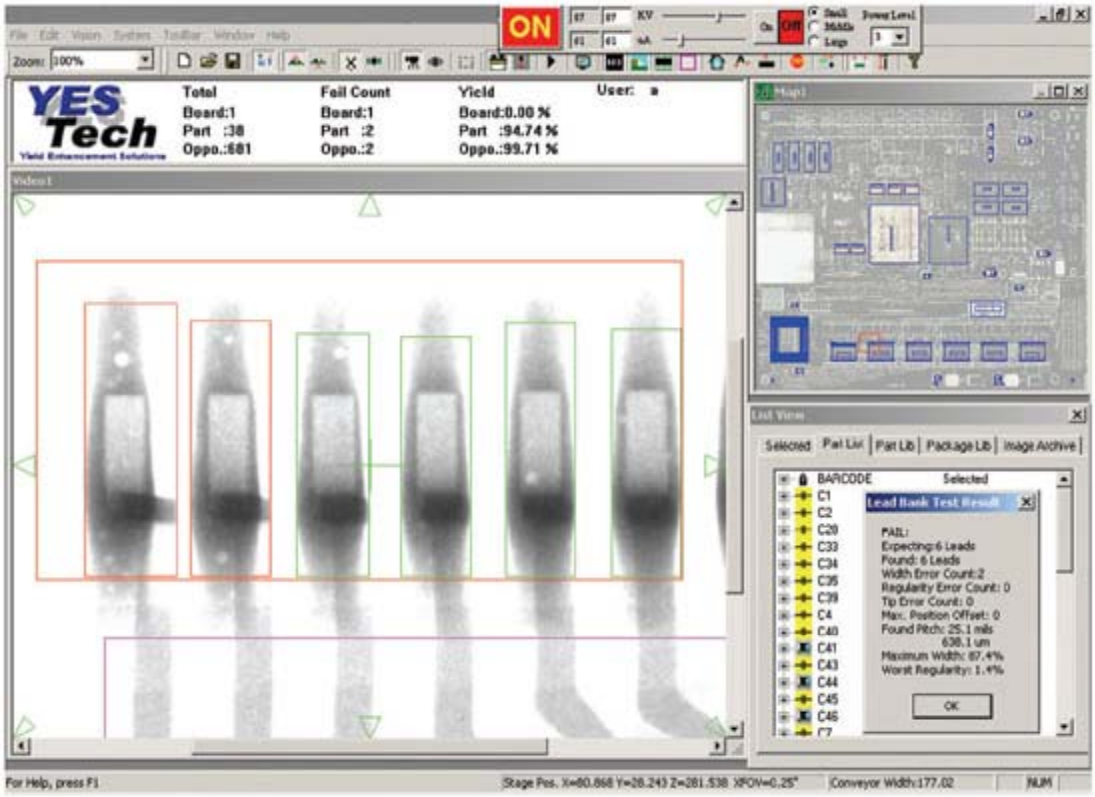

Figure 1. Screen Showing AXI of a Leaded Device

Adoption of AXI has gained momentum as component sizes shrink, boards become smaller with denser placements, and cycle times decrease. All of these factors cause a higher probability of errors occurring, such as missing, misaligned, or incorrectly soldered components (**Figure 2**).

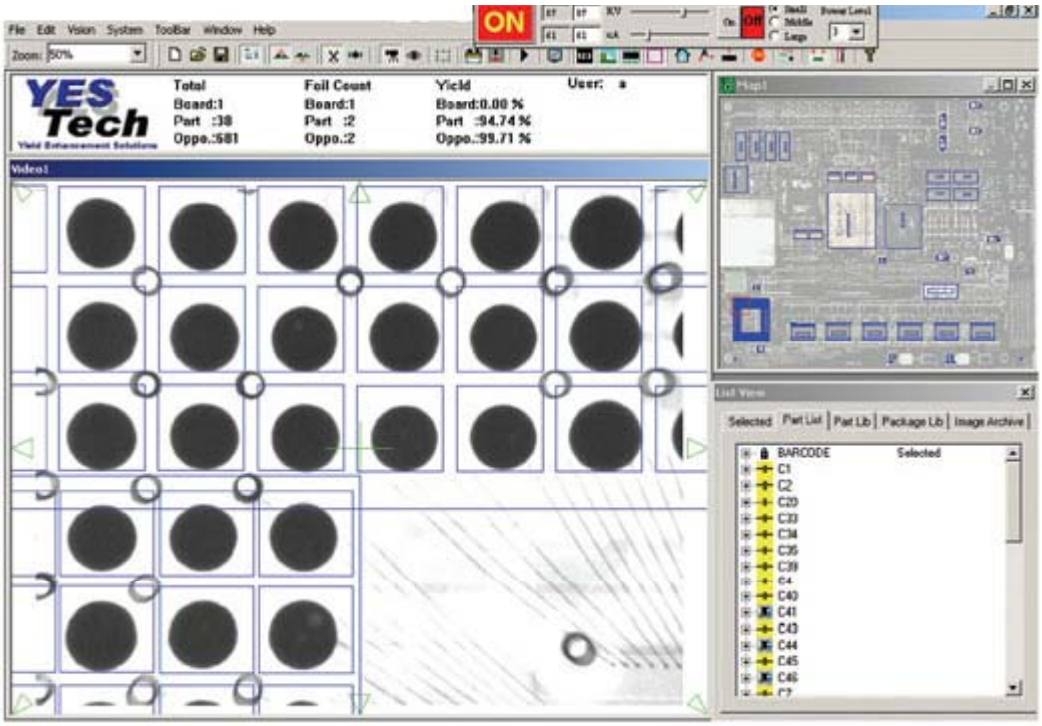

Figure 2. Screen Showing AXI of a BGA Device

The key to further adoption is for AXI to meet the demanding standards and lower-cost models of most PCB assembly operations. AXI system suppliers must offer equipment with a level of technical sophistication, quality, and reproducibility that will:

- Accurately detect and identify assembly and solder defects.
- Minimize false calls.
- Offer efficient operation in manufacturing environments. This includes keeping pace with the line rate and ease of use.

Types of Systems

There are two principal types of AXI systems:

2-D or Transmission X-Ray

With this technique, X-rays are generated at a fixed point source, pass through the PCB assembly, and form an image on an electronic detector. The image is converted into a digital image and transferred to a computer where the analysis takes place.

Transmission X-ray is widely used for single-sided boards in automotive and other high-reliability applications. Advanced image processing software now is available to distinguish topside components from those on the bottom side for inspection of double-sided boards. This is the most common form of X-ray inspection for electronic assemblies.

3-D X-Ray

This technology provides clear images of single layers or slices of the board to facilitate inspection of double-sided boards. The laminographic 3-D technique requires the X-ray source and detector to move in a circular pattern 180 degrees out of phase. Only features in one plane are in focus, and components and solder joints not in the plane are effectively blurred out.

The tomosynthesis technique creates 3-D images by combining multiple transmission images taken from different angles. Both techniques are commonly used today in X-ray inspection applications for more complicated electronic assemblies.

The proven results of AXI make it one of the most effective technologies for finding manufacturing defects in electronics assembly operations. Its acceptance is increasing, and it is successfully being used in ever-differing manufacturing environments.

Use of AXI systems will result in lower rework costs, better process control, and improvement of the assembly process to further reduce defect rates. The ultimate benefits are fewer field failures and improved profitability.

An Application

Adherence to quality standards is all in a day's work for a leading Michigan-based supplier of automotive integrated electronics technology, software, and product design. Lectronix serves OEMs and ODMs in the automotive, communications, and control industries. In conjunction with developing highly reliable products that survive demanding environmental conditions, the company adheres to stringent test and inspection guidelines backed by ISO 9001:2000 and ISO/TS 16949:2002 certifications.

Lectronix was an early adopter of several advanced manufacturing techniques that helped to meet high quality standards. In 1999, the company installed both AOI and AXI to verify part placement and solder-joint integrity. This inspection strategy helped the company ensure quality in all phases of production, resulting in high yields even on the most complex assembly runs.

Finding hidden defects makes AXI the logical choice for inspecting complicated boards or components under RF shields.

In early 2005, Lectronix decided to replace its outdated inspection systems. In addition to the equipment becoming dated, obtaining replacement parts was nearly impossible. The company was facing extensive downtime, and the current equipment setup time for new programs was taking several hours to as much as three days. Programming was difficult and required a specially trained employee to define all rules and create proprietary Lectronix parts libraries.

The company began looking at new equipment from some of the traditional manufacturers of automated X-ray systems as well as systems from YESTech, a supplier new to the company. Lectronix discovered that the YTX-6000 AXI System offered capabilities comparable to those of machines from other vendors at a significant cost savings.
In addition, comparable defect detection was possible with much less programming than required by competing machines. Also, the YESTech SPC software package proved helpful when converting manufacturing data to more of a preventative application tool.
The significance of the new AXI system cannot be overstated. In the past, the company was unable to fully implement AXI on many assemblies for two reasons.

First, the time to program the AXI system prohibited its use in many cases, especially for short runs in which programming time would create production bottlenecks. Second, many times board design would not allow adequate AXI coverage due to component shadowing, requiring additional time to create further custom part libraries if even possible.
The YESTech YTX-6000 addressed these issues and allowed Lectronix to quickly and easily further implement automated X-ray inspection across all product assemblies.
The recent setup of a new, very complex board demonstrated a large cost savings. The process required about one hour or less including programming of AXI for all components, not just BGAs. The old inspection equipment would have taken about 16 hours of programming time.

The programming efforts were shortened in part because the YTX-6000 does not require special programming languages. The new equipment was programmed quickly and easily, which translated to substantial operating cost savings.
The new system's reporting features provided detailed information, not only for quality monitoring and reporting, but also for on-the-line repair. Lectronix repair technicians can call up the board image and see exactly where the suspect item is located.
The SMT process has benefited as well. A noticeable increase in yields has been achieved by analyzing the data collected by the AXI system.

Three-Step Inspection Approach

The equipment also fits in well with Lectronix's tiered inspection procedure, which is a highly effective component in the quality program.

Prototype

Test and inspection methods including both AXI and AOI are used whenever possible for prototypes. The combination of methods quickly gets prototypes into the engineer's hands.

First Production Run

Quality is maintained from the first board off the line on the first production run. The standard procedure is to use AOI and AXI to verify the correct build of the first five boards of all production-run setups and at the beginning of each shift. This confirms the setup and that all SMT processes are in control.

Production

AXI allows Lectronix to constantly monitor the SMT process. Each board produced has a specific detailed inspection plan. Operators can shut down the production line if any of the inspection results get out of range. This constant feedback loop improves the process and prevents costly rework from being required. Any errors that occur are pinpointed so that they can be fixed immediately.

The Results

The ultimate benefit of AXI is seen as reduced field failures. Inspection and test processes improve the reliability of the product in the field. Because AXI can detect marginal solder joints, something not detectible by traditional in-circuit test, customers experience fewer product returns, resulting in lower warranty cost and lower overall product cost.

Lectronix was looking for value as well as enhanced capabilities from the new inspection equipment. For several weeks, products were tested on the previous system as well as on the YESTech machine and the results compared. In finding defects, the YTX-6000 was equal to or better than the previous equipment. This result allowed the company to confidently integrate the new machine as the primary inspection equipment without risk of decreasing yields.