Testronics

a tester company with vision

“INSPECTION BY EXCEPTION”

MODEL 505
AUTOMATED OPTICAL INSPECTION SYSTEM

Presented by

Testronics

November 14, 2000

Testronics Model 505 Bench Top
Automated Optical Inspection System

Product Description

- Automatic Optical Inspection system for PCB assemblies
- 18” x 24” inspection area
- Table Top Mounting
- Batch or Offline Operation
- Quick and Easy to program
- Color imaging
- Fault Coverage Includes but is not limited to missing components, reversed components, some solder defects, skewed or misplaced components, wrong size components, wrong color components, part present when it should be absent, and bent connector pins.
- Alternative to Manual Visual Inspection in a High Mix Environment

Ease of Use

- A vision system that can inspect product the same day it is delivered
- Can create inspection programs with missing or incomplete CAD data
- Lower skill level needed for inspectors
- Technician level support as opposed to engineer level
- Ability to handle false calls in an effective manner without spending days or weeks programming
- Improves the manual inspection process in a high mix environment rather than trying to obtain the unattainable 100% fault coverage
- Simple and effective – offering fault coverage rivaling systems costing 4-6 times more
- Graphical User Interface with Windows OS
- Can be used as a Viewer without Programming

Innovation

- Addresses the issue of “False Failures” associated with classical in-line Automatic Optical Inspection systems
- Removes the inconsistency associated with manual inspection
- A system design that keeps the cost low while providing superior performance
- Reduces the years of training required for traditional inspectors
- Provides a complete structured inspection solution by focusing the capabilities of human and machine
- Commercially available technology provides a high performance, low cost system
- Latest generation software provides user interfaces that are simple to use but complete in function
- Uses the best capabilities of both human and machine
- Concurrent Inspection during review

Value and Contribution to Quality

- Low Cost typically between $ 50k - $65k US
- Provides documentation and feed back for quality control
- Significant reduction in 1st article inspection time
- Provides structure and objectivity to the manual inspection process
- Quantifies a subjective process
- Improves process control and yield
- Reduces labor costs and improves efficiency
- Lower skill level needed for inspectors provides a scalable workforce
- Provides an alternative to electrical test: 1) on boards without test points 2) on boards with high frequency circuitry 3) and for low volume boards that cannot be tested due to the high cost of fixturing

Testronics is a manufacturer of Automated Electrical Test and Optical Inspection Equipment for the PCB assembly industry. Founded in 1982, we have a long history of designing, manufacturing, implementing, and supporting automated test equipment. Our product line has evolved and strengthened over these 18 years. Our most popular products today are our low cost manufacturing defects analyzers, our analog in-circuit test systems, our high pin count level IV backplane test systems, and our newest addition: The Model 505 Bench Top Automated Optical Inspection System.

We have brought quite a few new products to the market, experiencing the successes and failures that inevitably come along with product development. About three years ago, we purchased a company who was a manufacturer of automated in-line optical inspection equipment. Joining along with the industry AOI craze seemed to be the direction to move in order to keep up with the changing PCB assembly market. There are many reasons why AOI is very appealing. As ATE engineers, the limitations of bed of nails testing are all too obvious. The reduction of board size, increase in density, lack of test points, increase in communication type high frequency circuitry, and the high cost of fixturing and test programming make traditional In Circuit and MDA testing less and less effective. Today's board technologies require a combination of inspection and test tools to ensure only the highest quality products reach the customer.

Over the following year and a half we worked to implement the in-line AOI system. We soon discovered a significant gap between the capabilities of the technology and the expectations of the customer. Indeed, the industry as a whole was pronouncing in-line AOI to be the answer to detecting all process related problems short of BGA inspection. However, as often is the case, there is a very big difference between what is theoretically possible and what can be applied reliably within a production environment.

One of the biggest hurdles that had to be overcome was drawing a parallel between machine vision and human vision. So many times we look at a component and decide that it is "good enough". Unfortunately, machines have difficulty with "good enough". Of course there are many ingenious image processing algorithms, advanced optic techniques, lighting variations, and mathematical modeling functions available. These still fall far short of the human ability to make a subjective decision. Some companies have even tried to solve this problem by using what they call artificial intelligence. As currently being implemented in most systems, this is really just a sophisticated statistical feedback loop that updates the tolerances dynamically. No real subjective pass or fail decisions are actually made.

The ability of a machine vision system to say "good enough" is almost possible with enough statistical processing. Unfortunately, the amount of tuning and programming required as well as the large number of samples that must be inspected precludes this type of system from actually being implemented by the majority of manufacturers.

As a particular example, an in-line AOI machine that sells for upwards of $150k - $250k, can mathematically model each component shape, position, and solder fillet. Each defined area of the component can have as many as 40 different programmable attributes. The system was very fast and very accurate, reaching a false failure rate of less than 100ppm in most applications. However, it takes years for an engineer to learn to program it and then weeks to program each board. If weeks aren't spent, and every variable tuned exactly, the false failure rate is so high that every board is rejected. This renders the concept of in-line AOI practically useless. Even with all this effort, the program needs to be

tuned as the process and materials vary on a weekly, sometimes daily basis. In spite of the difficulty in programming, this high speed, in-line inspection capability is a feasible solution for very high volume, long term products. We see quite a few successful in-line AOI installations in these high volume environments. However, the majority of manufacturers do not have the time, personnel, or volume of a single part number to invest such resources as required for success. Most organizations support a higher mix, lower volume philosophy.

With the focus on outsourcing, most board assembly is now done by contract manufacturers. Their ability to be flexible can make or break their business. In addition to flexibility many of the assembly shops cater to a lower volume and higher mix customer. They must meet these needs on a quick turn basis, while keeping their yields and quality higher than their competitors. In many contract manufacturing groups, less than 50% of their assemblies are tested prior to a final system test, (if they are tested at all). Of course, the recent advances in the pick and place equipment provide many tools to control the assembly process. Although this does greatly reduce the number of manufacturing failures, it doesn't catch everything. Visual inspection is still a major part of most organizations defense against shipping boards that have manufacturing faults present.

The development of the Model 505 AOI system is the answer to the question, "What can AOI do for the PCB assembly industry, without taking weeks to program and costing hundreds of thousands of dollars?" We focus on what the customer needs as opposed to what the AOI manufacturers think is the solution. Again, it comes down to reality versus theory. We admitted to ourselves that optical technology for PCB inspection applications is subjective at best and at worst, almost unusable. This acceptance of facts allows us to focus on what **will** give the customer the value necessary in real world applications to support our new Model 505 as a long lasting product.

Manual inspection is incomplete, inconsistent, error prone, and results can vary from operator to operator, shift to shift and even with the time of day. Inspectors are required to make thousands of decisions every day. Fatigue and the level of training are significant factors in the effectiveness of manual visual inspection. These and many other factors result in a slow, undocumented, unreliable, and expensive means of producing a quality product. While the AOI system manufacturers were focusing on the expensive in-line solutions, no one was really help the inspector. The Model 505 improves the manual inspection process by increasing the fault coverage, the throughput, the accuracy, and decreasing the costs.

The Model 505 coins the saying "Inspection by Exception". The 505 automatically scans and identifies components that appear different from the reference "golden board". Only those components in question are brought to the operator's attention and are individually displayed on the monitor at a high-resolution 10X color magnification. The inspector is prompted to review the questionable items by using a set of specifically designed software tools. The strengths of the inspector are maximized because they only review the components that appear different from the golden board.

For example, on a board with 1000 items, an inspector will be effective on 200 to 300 items. By using the Testronics model 505, all 1000 items will be inspected. The 10 - 20 items that the system is unsure of will be displayed for inspector to review. The inspector reviews each subjective item and with a single key press decides if the item is acceptable or not. By utilizing the Inspection by Exception technique, the drudgery of inspection is removed. The items the inspector actually looks at is reduced by 1/100th while the total number of items inspected is increased from 20% - 30% to almost 100%. This technique also overcomes the problem of "false failures" or "false calls" that plague the in-line AOI systems.

During the development of the Model 505 AOI system, the Testronics design team overcame many challenges. The first was how to handle “false calls”. Instead of trying to eliminate them, we accepted that “false calls” are unavoidable due to the nature of image processing, the variations in parts and processes, and many other variables in PCB assembly. We designed the software with tools that give the inspector the ability to quickly categorize the false calls as passes and name the real faults with their own failure codes.

The second challenge was to keep the cost low. The Testronics 505 utilizes commercially available components from an advanced vision inspection industry and coupling them with the performance of a high end PC platform. This combination allows Testronics the ability to provide a low cost, but very advanced inspection system.

The third challenge was to be able to handle large board sizes, odd shaped boards, panelized boards and also accommodate tall components on both the top and bottom of the board. Our first prototype would only handle a board size of 12” x 18”. There was no clearance on the bottom and only 1.5” clearance on the top. This is typical of the other systems on the market. After changes, our production 505 has an inspection area of 18” x 24” with a 1.5” clearance on the bottom and 5.25” clearance on the top. The system can physically hold a board up to 32” in size. This allowed us to be far more flexible than other systems as well as handle large loaded backplane assemblies.

The fourth challenge was being able to do an intelligent inspection with very little programming. This had to accommodate customers with data and without data. We developed a unique software screen that allows the import of data, the ability to quickly build library parts, rotate and align data as a composite or as individual component, or build the entire program without any data at all. This screen lists all reference designators and x,y locations. The programmer can zoom in and out at various levels of magnification. Text comments and part numbers can be also be entered for display during inspection. Simplicity is the key. We have limited the number of variables for each algorithm. This keeps the programming concepts straight forward and simple.

Sometimes cleverness is found in simplicity. Our design engineers kept the mechanical hardware simple and worked hard to keep the software graphical and easy to understand. Optics and image processing can be very complicated if allowed to get out of hand. Many other equipment manufacturers are implementing multiple cameras, programmable lighting, and mathematical modeling of solder joints and components. This takes advantage of the technology to its maximum capability. However, the small increase in fault coverage is gained at a very high price. Programming is increased from a few hours to days or weeks. System maintenance and costs are increased four or five times and the technical expertise to maintain the system is increased from a technician level to a senior engineer with years of training. We have found that our best customers and our most excited prospects are those who have tried in-line AOI. They have either given up or been forced to lower their expectations to a point that left them feeling as if their vendor and the technology failed them.

Testronics redefines the meaning of automated optical inspection:

The Model 505 is three tools in one:

1) **High Resolution Color Viewer** – This level requires no programming and no tooling. Simply put the board on the system and acquire the images. The system will then compare all subsequent boards to the first by flashing between the first image and the current image. This will step the operator through a systematic inspection of the boards with a 10X magnification of high resolution color images. Some of the advantages are that the inspector will need considerably less training to be able to distinguish between what is good and bad.

2) **First Article Inspection** – Almost no programming is required for this. By using the list of reference designators and x,y locations, the system can be set up in minutes to perform a first article inspection. If no data is available, a bare board with silk screen can be used to locate the components. At this level, the system will automatically highlight and locate each component. The inspector can then determine placement, presence, and part markings. The correct part markings and no load identification can be displayed as the inspector is looking at the corresponding part.

3) **High Level Production Inspection**: The 505 can be an intelligent automatic inspection system with fault coverage rivaling AOI systems costing tens of thousands of dollars more. By using standard pick and place data, Testronics provided part libraries, and the 505 edit/align graphical programming screen, the system will automatically detect errors in part placement, part orientation, connector pin presence, solder in holes designated for through hole parts, and part presence or absence.

The benefits of using the Model 505 are significant. Used as a viewer the system removes eye strain from the inspectors job. The inspector now becomes significantly more efficient and reliable. Since the good image is displayed simultaneously, the training level required for the inspector is reduced. The inspector does not have to be taught what a good component looks like because it is displayed for each component inspected. This makes the inspection process scalable since production management no longer needs inspectors that have years of experience. Labor can easily be added according to the rise and fall of production volumes.

Many PCB assembly houses can justify the purchase of a Model 505 bench top AOI system based solely on the decrease in time for line change over and first article inspection. In some high volume houses, a line down during change over can cost $ 1000’s of dollars an hour. This is just for the line equipment. When unused labor is added to this, every minute counts significantly. Most companies are performing first article by manually verifying the presence, orientation, and part number of each component. The reference designator, x,y location, and part number is read off a printed sheet and then located on the board. The inspector checks off each component as they are verified. The typical time for this to be completed is anywhere from 2-5 hours. With the 505, a first article inspection can be performed in minutes instead of hours. Because all reference designators, their part numbers, and locations have been automatically loaded into the system from either the CAD or the pick and place data, the inspector no longer has to search for the location of every component. The system steps the operator through an alphabetized list of every component. Because the system is small and portable, the same system can be used for multiple lines. This can save the company $ 1000’s of dollars a day.

Using the system for intelligent batch inspection of every board will increase the yield, increase throughput, document the process, reduce the training of inspectors, reduce the number of inspectors needed, and decrease scrap. Some customers are actually using the system to inspect boards that are in

their scrap pile. One cell phone manufacturer who is using some in-line AOI, has as much as a 30% fall out at functional test. Because the boards are so dense and the components so small, many of the defects are still getting through the in-line AOI. They have found that one of their biggest problems is simply missing 0402's and 0201's chip components. Since the 505 can find these faults quickly, the boards can be repaired and the company can recover lost revenue.

As our installation base of the product becomes larger, we are seeing more and more uses for this system. Customers are using it in ways we did not foresee. One large contract manufacturer is using the system to simply verify that holes are not filled at the bare board level prior to connector insertion. They were able to reduce their labor from three people to one and increase their total fault coverage.

Our experience with the expensive in-line AOI technology gave us insight that we would not have otherwise had. What we learned from the customers, was that they were wary of and disappointed in AOI. They did not want to spend hundreds of thousands of dollars or spend weeks programming. The existing equipment available was simply not providing enough value. What was gained by implementing AOI did not come close to equaling the expense and resources it consumed. By accepting the limitations of the technology and identifying the needs of the customer, we were able to produce a product that does provide significant value. The manual inspection process needed help. The inspectors needed help. The drudgery, inconsistency, and bottleneck of human inspection was not being addressed. The Testronics Model 505 does address all of these issues. It improves an imperfect process. Most importantly the Model 505 fits the realistic capabilities of optical technology to the industry's applications and the customer's needs.